

LOW TEMPERATURE DISTILLATION

HOME OIL SUPPLY AND THE
UTILIZATION OF "WASTE" COAL

BY

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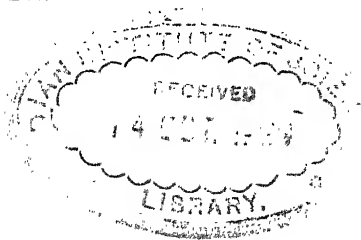
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PREFACE

IN this work the authors have traversed the gradual emergence of the low temperature principle from early times and the different methods employed in the carbonization of coal. This has involved references to coke-oven practice as well as to gas manufacture, examples of true carbonization, inasmuch as the coal is necessarily carbonized mainly to secure the products desired, namely, gas and coke.

Low temperature proper, that is the subjection of coal to those temperatures at which the greatest yield of oil, of the highest quality, can be obtained, is of quite recent development, although we find that, in 1865, Gesner employed low temperature, that is between 371 and 426 degrees C. and obtained 68 gallons of oil from a cannel coal.

The authors have endeavoured to bring home to the reader the possibilities that now exist of treating the coal of this country in a scientific manner, and that the adoption of the principles underlying the processes referred to would provide the whole of our requirements in the way of oil and smokeless fuel, and at the same time, the complete utilization of coal now being wasted above and below ground.

The provision of these fuels is the most urgent problem of the day, and there is no technical reason why our coal resources should not be so treated as to yield the products referred to in sufficient quantities and of high quality. There exists, however, in some quarters, a strong prejudice against the initiation of new practice in coal treatment, a prejudice such as was manifest when the by-product coke-oven was introduced into this country and in America. Almost identical arguments were raised against the latter as are now advanced against low temperature practice, namely, that the solid residue obtained was of no higher quality than, and in some respects, inferior to that produced under the old methods.

Apart from the fact that these assertions are erroneous the destructive criticism levelled against a movement which would

place Great Britain on a sound economic basis, by providing it with a cheap smokeless fuel, by making profitable the enormous amount of coal completely lost in mining and handling, and by producing ample supplies of high grade oil, is to be deplored and is technically unjustified.

The authors contend that this is not a problem the solution of which should be determined by those who consider personal or vested interests before national welfare and prosperity. It is far too vital a matter to be side-tracked by mere prejudice and closer co-operation should exist between those working with one aim and towards the same object.

Those who depreciate the efforts made to bring to a successful issue the treatment of coal so that the criminal waste now occurring in the industry is completely abolished, and the conservation of the valuable products is achieved, are relegating the country's welfare to a position behind individual and vested interests. The industrial need of the moment is cheap fuel, and of almost equal importance is a home-produced oil supply. How essential is the latter is proved by the fact that in 1914 no less than 88·84 per cent of ships constructed were fired by coal ; ten years later this figure had declined to 68·87 per cent, indicating a significant advance in the use of oil-burning in the Mercantile Marine.

The same movement was shown in motor ships. In 1914 the proportion of this description of vessel, on the tonnage constructed, stood at 45 per cent ; in 1923 the figure had risen to 256 per cent. Such figures are eloquent of a quiet, insistent revolution in power production.

Both the national requirements referred to can be attained if the policy and practice described in the following pages are adopted on a large scale.

The experimental period of low temperature treatment is past, and the experience gained has enabled our engineers and chemists to design methods and plants capable of being worked, not only with technical, but also with commercial success.

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LOW TEMPERATURE DISTILLATION

CHAPTER I

INTRODUCTION

THE abundance of the coal deposits of this country has induced a spirit of profligacy in the use of the mineral. Originally Great Britain was the richest coal country in the world, estimated on its area, both in regard to quantity and quality; but the years have taken a heavy toll of these resources, and the very fact of the vastness of these has encouraged a wastefulness in the methods of use, which is not only eminently unscientific, but grossly criminal, seeing that by so doing, incalculable quantities of greatly needed products are being wantonly dissipated. Burning coal under boilers and in the open domestic grate in its raw state can be, and should be, abolished. It is true that the last few years have witnessed a certain amount of progress in securing more rational treatment of the mineral, but the progress is far too slow. Improved furnaces and grates have been introduced, but this movement is merely side-tracking the main problem. The brutal fact still remains that millions of tons of coal are consumed every year, involving the loss of at least from 15 to 20 gallons of oil and associated valuable by-products per ton of mineral, and without a fraction of profit being gained.

Apart from the losses due to burning coal without pre-treatment, a very serious wastage occurs due to casting aside large quantities of fines and small coal resulting from handling the coal at the pit's mouth. This is, in the great majority of cases, thrown on to the dump, although it represents, by proper treatment, a source of considerable profit. In addition to this, a large amount of good material, although mined, is left in the pit, equally valuable for treatment, and for which

the miner receives no payment, and the owner is wilfully depriving himself of an addition to present revenue.

Coal Consumption in this Country.

It is estimated that the consumption of coal in this country for steam-raising and domestic use amounts to a total of, approximately, 150 million tons, and taking the minimum figure of 15 gallons of oil obtainable from this quantity gives us a total home supply of 2,250 million gallons of crude oil, or 9 million tons equal in value to natural crude oils. Calculating this at the present price of crude oil in this country, it will be seen that an enormous amount of wealth is being allowed to pass into the atmosphere without any attempt at its conservation. Large quantities of inferior coal are thrown on to waste dumps, while anthracite is used only on a restricted scale. All of this in its entirety could be profitably absorbed for conversion into briquettes.

The Position in Belgium.

The position of things is quite different in Belgium where the output of coal amounts to about only 20 to 25 million tons a year, and whose people are therefore compelled to exercise economical methods or pay high prices for the imported mineral. From the inferior coal and slag produced, the Belgians manufacture no less than 3 million tons of fuel in the form of briquettes. This quantity represents 12 per cent of the total produced, while England, with a production of over 250 million tons, manufactures only 2 million tons of briquettes, or less than 1 per cent of the total quantity produced. Even, therefore, compared with such a small country as Belgium, we are, from the scientific standpoint, infinitely less advanced in this matter of the proper utilization of coal.

Briquetting.

Coal briquetting is an essentially Belgian industry, initiated as far back as 1818, but it was not until 1858 that its advantages were fully recognized and developments on a large scale occurred. After the opening of the Ruhr coalfields the Germans were quick to recognize the advantages of coal

riquetting, and started production on a large scale, not only on ordinary coal, but also with brown coal or lignite.

Many disappointments have been experienced in the course of the experimental work carried out in this country, chiefly due to lack of experience and practical knowledge. Briquettes were manufactured from best waste Welsh coal, but these could not be used in locomotives, nor under marine boilers, as they were far too rich in hydrocarbons. The blending of various qualities of coal has, however, reached in Belgium almost perfection, and the briquettes produced are practically smokeless, and of very high calorific power.

Oil from Coal.

Desultory attempts have been made during the last two decades in this country to treat the coal in such a manner as to conserve the oils and produce a good residual fuel. The success with which some of the employed processes have been worked indicates very clearly that the treatment of coal in a satisfactory manner can be carried out, and that there is, therefore, no excuse for the continuance of a policy which is extremely detrimental, if not dangerous, to the welfare and prosperity of this country.

In the early days of low temperature distillation, the crude oils were not of such a character as those obtained in a natural liquid state from the oilfields. The improvements in the methods which have, however, been introduced during the last two or three years have resulted in the production of crude oils of a paraffinoid character and equal in value to the natural crude oil. This change has placed the whole problem on a new basis, ensuring as it does the production of a crude oil from which light products, equal in value to those obtained from natural crude, can be secured. From the point of view, therefore, of oil values, low temperature distillation has now attained a commercially sound position. There are in existence at least half a dozen systems which are capable of guaranteeing 60 gallons of oil per ton from material such as shale and torbanite, containing 65 per cent of volatile matter, while in the case of Natal coal¹ containing 32 per cent of volatile

¹ The plant working on this coal was established in Bombay, the mineral treated being imported from Natal, S. Africa.

matter, 34 gallons of oil have been obtained, and in the case of English coal containing from 28 to 30 per cent of volatile matter, an average yield of 20 gallons of oil can be safely relied on.

The Pitfall.

The great mistake which has been made by the majority of those who have turned their attention to the invention of a process whereby the by-products from coal could be obtained has been that they have set out with the idea of securing as great a variety of products from the coal as possible, instead of directing their energies into one definite line. It is impossible to secure a large quantity of oil and at the same time produce satisfactory quantities of good residual fuel and gas. The object which should be kept right in the forefront is that of producing the largest quantity of oil, and using whatever residual fuel is obtained for briquette manufacture, combining this with waste bituminous coal, of which such vast quantities are available.

The Requirements of Solid Fuel.

This brings us to the other factor in the problem, as in dealing with coal one has to consider the interests and requirements of solid fuel producers and consumers. The solid fuel residue derived from the distillation of coal is in the nature of a high grade coke, and can be crushed and combined with waste coal for the manufacture of briquettes. These briquettes, if properly constituted and made, have a far higher calorific value than the original coal, and can be employed for any steam-raising purpose as well as for domestic use. The question of briquetting has, in Belgium, become a fine art, all waste being crushed, washed, concentrated and mixed with inferior coal and transformed into briquettes at a very nominal cost in well-devised plants working automatically and with a labour outlay of less than one shilling per ton. The chief expense incurred is in respect of the binder, which up till recently has been confined to pitch produced from coal tar. For some time pitch stood at a prohibitive price in Great Britain, and successful efforts were made to adopt a pitch produced from heavy petroleum ; but if the low temperature

distillation of coal is carried out efficiently there should be no need to resort to imported mineral for a binder. From coal treated by the low temperature process, oil is extracted in as large a proportion as possible, and the friable coke obtained turned into briquettes as suggested above, while the pitch resulting from this process can be used as the required binder.

The Coke Oven.

The coke oven is already producing valuable by-products, and blast furnaces, etc., supply free fuel for boilers and steel furnaces. So far the obtaining of coke for metallurgical purposes implies the use of high temperatures which, up to the present, and with all the improvements made, is still over 1000° C. at the initial point, and the resultant products are more of the aromatic or acid series than paraffinoids. There is, however, already some improvement in coke-oven practice, and no doubt this will continue. For ordinary industrial fuel, steam boilers, locomotives, etc., and for domestic purposes of every form, the future lies in passing all the bituminous coal through low temperature carbonization, extracting the maximum of oil possible of the highest quality, and forming ultimately a synthetic coal, smokeless and adapted in composition and form to the purpose for which it is destined.

The Low Temperature Process.

Low temperature carbonization with super-heated steam will extract oils and preserve their paraffinoid character, avoiding the production of aromatic products and paraffin scale. The matter of briquetting the friable coke residue is such a commonplace affair abroad that anyone who has inspected the developments in Belgium, France and Germany, can realize the backwardness of England in the matter, and it is evident that this is due not only to prejudice, but to the fact that this country possesses such potential supplies of coal which have shown no signs yet of becoming exhausted, and that, in consequence, there is no necessity to conserve supplies. The fallacy and danger of such an attitude must be obvious to everyone.

Brown coal and lignite can also be treated in the same manner as the higher grade coal for oil extraction and briquetting, and this has been done in Germany, France and Russia for a considerable time, while it has also been recently introduced into America with success.

Financial Facts.

The commercial aspect of low temperature processes is, of course, the touchstone of utility and practicability of any new process, and we may introduce a few figures here relative to this point. The capital expenditure necessary to establish a plant capable of dealing with 1,000 tons and including retorting, etc., may be stated to be from £40 to £50 per ton treated, while the cost of treatment, including amortization and depreciation, should not exceed 4s. to 5s. per ton. As far as briquetting is concerned, the cost would naturally vary according to the nature of the coal dealt with, but taking an average figure, it may be put down at from 1s. per ton to 2s. per ton, the necessary binder or pitch being a by-product of distillation. From these figures, which are based in most cases on actual practice, it would appear that for securing the whole of the valuable products, gaseous, liquid and solid from the original coal, the working costs would amount, at the outside, to 7s. per ton. In regard to the utility of the oils obtained from coal distillation, there is now little doubt as to their market value, and to the demand for these. The profitableness of such a venture is assured, especially when taken in conjunction with the manufacture of briquettes, the extensive use of which on the Continent and elsewhere has already been referred to.

Diesel Engine Fuel.

There is one direction of disposal, however, to which reference may be made, namely, that of Diesel engine fuel. The oil produced from coal could be very easily prepared to make it eminently suitable for use in internal combustion engines, and once having a reliable home supply of this description of oil there can be little doubt that considerable impetus would be given to the adoption of the motor-ship.

One of the obstacles standing in the path of motor-ship

development is undoubtedly the lack of extensive and low-priced oil supplies. The total oil output of the world is now about 1,000,000,000 barrels, so that taking four barrels of oil as equal to one ton of coal, the oil supply is equal only to 250,000,000 tons of coal per annum, or not sufficient to replace the coal mined in Great Britain alone. It is here, therefore, apart altogether from the production of petrol and other products from coal distillation, that producers of oil on the low-temperature principle should find an available and profitable market. The main problems of low-temperature carbonization have now been solved which means that all the coal of the country, non-coking as well as coking, can be carbonized successfully. Apart from the existing high temperature processes employed at gas works and coke ovens which absorb between them about 38,000,000 tons of coal per annum, there would be available at least 150,000,000 tons yearly for distillation by modern methods. This would yield, among other products, at least 450,000,000 gallons of motor spirit, and 250,000,000 gallons of crude oil, of which at least 50 per cent is high-class Diesel oil. Under such conditions we could develop the economical Diesel engine, not only for marine purposes, but for stationary land and locomotive services as well. In addition to this an enormous reduction in the national coal bill would accrue as well as a great saving in subsidiary local and national expenditures due to the burning of coal by the present wasteful methods.

CHAPTER II

EARLY EXPERIMENTS

THE records of the early experiments in the distillation of coal are of extreme interest not only to the technical historian but also to those engaged in the chemical and industrial aspects of science. As far back as the seventeenth century experiments were carried out having as their object the extraction of products from coal by means of destructive distillation. The chief purpose of these experiments appears to have been due to the ignorance which prevailed in regard to coal and its use, for in a patent taken out by Becher in 1681 he stated that he had found "a way not merely to burn both peat and pit coal into good coal which did not smoke or stink but would smelt equally as well as wood." It is evident from this that he obtained by distilling off a certain proportion of the volatile constituents, a residue to which was given the name of coke. This endeavour to make coal as it was then burnt a less noxious fuel undoubtedly accidentally led to the discovery of the valuable products which the mineral contained. Mechanical appliances in those early days were in a very primitive state and the methods adopted to obtain combustion were so imperfect that vast quantities of smoke and noxious gases must have been given off and the atmosphere poisoned with sulphurous fumes. This is the picture presented so vividly, yet in so few words, in the specification drawn up by Becher for his method of distillation. Judging from the wording of this patent, it was not the chief object of its originator to engage in the distillation of coal for the purpose of obtaining the products it contained but merely to convert coal as far as possible into an innocuous fuel for smelting purposes. This, however, is of little account, since in the course of this process products were obtained and the utility of these recognized, thus laying the foundation of future industries. It was natural that having secured his main product, Becher's attention should be attracted by the residual matters, pitch and tar, and he was in a measure correct

n asserting that these had never before been "found out or used by any other," although we have Biblical authority for the fact that pitch was known and used in the days of the Pharaohs. It may be allowed, however, that Becher's treatment of coal brought the possibilities of its distillation more clearly before enlightened scientific minds, which were immediately, in England and on the Continent, directed seriously to the matter. Tar was evidently distilled from wood in Sweden prior to this, as Becher refers to it himself and compares the product he obtained as equal to it and in some operations even superior. Whether this treatment of coal was carried out to any extent at that period it is difficult to ascertain as there are few, if any, records to this effect. The gases which were given off during the process of distillation do not appear to have been investigated nor taken any account of until more than fifty years later when Clayton, in carrying out his process discovered that combustible gases were formed at the same time.

From this time onwards a great deal more attention appears to have been paid not only to the use of coal as a fuel but also to production of coke for smelting purposes as a substitute for wood charcoal, which had been almost wholly employed. Simultaneously with this extended use of coke attention was directed towards the by-products given off during the process of coking. Among the products which attracted the most attention was that of tar and methods were introduced for its recovery. This evidently led to the introduction of a special furnace by which the coal was coked and the tar recovered. In this process a muffle furnace was employed, and was at work in Sulzbach, near Saarbrücken, previous to the year 1768. It is evident from general historical records that the possibilities of coal as fuel and as possessing valuable products, obtained only by means of distillation, absorbed a considerable amount of attention from the scientists of those times. Unfortunately, a great deal of the investigatory work which must have been carried out was not recorded, and almost the only evidence available is that obtainable from patent specifications.

For the next link in this chain of progress we have, therefore, to go to this source of information, from which it is ascertainable

hat a patent was taken out by the Earl of Dundonald in the year 1781 for an invention for coking coal and entitled, "A Method for Extracting or Making Tar, Pitch, Essential Oils, Volatile Alkali, Mineral Acids, Salts, etc., from Pitch Coal." This was a very ambitious effort, and as might be imagined was never wholly fulfilled and, in fact, did not carry the science of distillation very much farther than it had already reached under previous patents. At this time the manufacture of coal gas was not carried out on a scale to any extent, but was regarded only as a by-product of the process adopted for eliminating gas from coal. The next investigators to come upon the scene were Lebar and William Murdoch, and it was due to the efforts and ability of the latter, together with his pupil, Samuel Clegg, that the foundation of a new industry, based on the distillation of coal, was laid. With the results of the previous investigations at hand and recognizing the possibilities which were, no doubt, brought to light by Clayton in 1737, Murdoch directed his abilities to one specific object, namely, the distillation of coal for the production of gas for illuminating purposes. The outcome of these efforts was the erection of a private gas plant in the engineering works of Bolton and Watt in the year 1798. Some time, however, elapsed before the methods and appliances which Murdoch had introduced were in a sufficiently advanced state to make them suitable for the supply of gas on a large scale, and it was not until 1813 that the first public gas works were erected in London. It is evident from the study of the whole of this early work that high temperatures were employed in coal distillation, for the reason that the main object at which the investigators aimed was the securing of a fuel which, deprived of a large quantity of its volatile matter, would be suitable for smelting purposes. The end of the eighteenth century, however, brings us to definite points in this branch of work. In the first place, the manufacture of coke for metallurgical purposes was an established fact, and the distillation of coal for the purpose of extracting therefrom the gas, which could, after certain treatment, be utilized for illuminating purposes, reached the first stage of commercial success.

It is when we arrive at the end of the eighteenth century

that we find a broader view being taken of the subject of the distillation of carbonaceous substances, and we must bear in mind, therefore, with the later developments which have taken place that the fundamental principles had already been laid down by Clayton and Murdoch. The application of these principles to other substances, important as they have been from commercial and industrial points of view, are but the adaptation of the main ideas demonstrated years previously. There can be no doubt that the knowledge of the efforts and success of the English inventors, already referred to, had extended to Continental countries, and these efforts inspired the scientists of the Continent to make attempts in the same direction, and in 1788 Krunitz, in carrying out investigations into the possibilities of "earth coal," or lignite, found that he could, by distillation, obtain what he termed a rock oil. Subsequently to this progress seems to have been somewhat retarded, although there is little doubt that continuous work was being carried out in the directions indicated. A number of patents were taken out for distillation processes, among which was a rotary retort by Clegg in 1815, but which, however, in practice, proved to be unsuited for the work.

The next important landmark that we find in this connection is the discovery in 1830 of paraffin as a distillation product, by Carl Von Reichenbach, who was the first to investigate this product and to describe its chemical and physical properties. It was about this time, apparently, that attention was directed towards bituminous shales. This mineral attracted the notice of Laurent, who engaged in experiments on its dry distillation. In conjunction with this work Selligie and De La Haye produced from this shale tar on a large scale and the industry established at that time is still in existence in France. Some years later another material was taken in hand, namely, peat, and from this Runge is stated to have manufactured candles of the paraffin recovered from peat tar. About this time, that is 1850, the enormous peat mosses of Ireland were brought into the field, and a distillation plant was put down in Kildare for extracting tar, which was subsequently worked up into other products. Similar efforts were being made on the same lines in Austria and Germany, but, as might have been expected,

the enterprises failed from the commercial point of view. Scotland also was the scene of a number of distillation plants, which suffered a like fate.

It was, however, from the attempts which had been made in his native country that James Young conceived the idea, which formed the basis of the present thriving industry, of the distillation of shales in Scotland. He commenced his operations on crude oil, which was obtained from a coal mine in Yorkshire, but the supply of oil failed and he had to cast about for other mineral products. A variety of coal was experimented with first of all, but this was soon relinquished as unsuccessful. His attention was then directed to Boghead coal from Torbanehill, and in this he discovered a suitable material for distilling. In his early efforts, Young employed low temperatures for his process, and by this means he was able to extract over 100 gallons of crude oil per ton. The success of this venture naturally attracted the commercial men of America and Germany, to which countries large quantities of this Torbanehill mineral were exported. The supply of this description of coal, however, soon began to decrease, and again other materials had to be sought for. It is interesting to note that during the period when Young was at work in Scotland distillation plants were at work in Canada treating Albertite shale, which was for a short time quite an important industry.

The bringing in of the first drilled oil well in Pennsylvania was practically the death-blow to Young's enterprise, as the comparatively cumbersome and lengthy process of distillation was relinquished for the supply of liquid oil from wells. The opening of this new era, however, gave an impetus in one direction; it set Young casting about for new material once more, and this he found in the bituminous shales with which Scotland is so prolifically endowed. Thus was laid the foundation of the present Scotch shale industry.

This brief record of efforts and endeavours, covering nearly two centuries, indicates very clearly the end at which these investigators and inventors were aiming, at the same time revealing definite lines of development which were taken up and exploited by their successors. These lines of development have been such as to make for the establishment of two main

branches of industry, namely, the manufacture of illuminating gas, and a fuel from which a large proportion of volatile constituents have been extracted by the distillation of coal. The fact that oil was recoverable during this process was recognized by one man, namely, James Young, and to him as well as to all previous investigators is due the honour of proving that under certain conditions the valuable products obtainable from coal can be recovered and successful and profitable industries built up. It is noticeable, however, that very little attention was paid to the use of low temperatures and the advantages obtainable from these were apparently unrealized. It has been proved conclusively that in the splitting up of coal by distillation far more valuable products can be obtained, while at the same time the valuable properties of the mineral are conserved, than by using it in its natural state as a fuel. In carbonizing the coal for gas-making purposes and in treating it for the production of coke, what are to-day very valuable products are lost, and it is from this point of view that this treatise has been written.

CHAPTER III

THE CARBONIZATION OF COAL

THE carbonization of coal is carried out for two chief purposes, one is for the manufacture of gas, either illuminating or power, the other for the production of coke. The distillation of coal having as its main object the securing of its volatile constituents is not yet commercially engaged in; although as far back as 1898 Dr. Beilby remarked that he was "fairly confident that when the proper time arrives we shall see coal separated into its volatile and non-volatile constituents, as shale is at present." In the opinion of many authorities this time has now arrived, and it is in consequence of this that the following brief review of the methods in vogue for the extraction of certain products from coal, has been undertaken. Not far short of three centuries have passed since coal was treated for the purpose of depriving it of a large proportion of its volatile constituents. Apparently, however, no definite record indicating when coke was first employed as fuel exists. One fact, however, is clear, namely, that this product was in use long before the value of the gases given off during its manufacture were fully realized. Until a comparatively recent period coke was produced by burning coal in heaps.

A negative proof that coke was manufactured previous to the year 1657 is found in a patent specification drawn up by one Jeremy Buck in the year 1657. This worthy "obtained a patent for making iron from stone-coal, pit-coal, or dea coal without charking," and the same authority states that the verb "chark" means "to burn to a black cinder," whereas the meaning of "char" is defined to be "to burn wood to a black cinder."¹ In 1686 coal was charred in exactly the same manner as wood; and the coal thus prepared was called "coak," which was capable of producing almost as strong a heat as charcoal itself.

¹ Report of Royal Commission on Coal, and Percy's Metallurgy-Fuel.

As much as for its historic interest as for its value in revealing the fact that a by-product of oil was secured and its utility recognized and applied, we quote an enlightening extract on the subject from Percy's standard work on metallurgy—

“Long anterior to Murdoch's great invention of lighting by coal-gas, experiments had been made by various chemists on the nature of the products of the destructive distillation of coal. Early in the last century, Hales indicated to the Royal Society the fact that half a cubic inch or 158 grains of Newcastle coal yielded in distillation 180 cubic inches of air (gas). Newmann states that 48 ounces of pit-coal distilled in a glass retort, with a fire gradually increased, yielded 2 ounces 7 drachms of phlegm, 2 ounces and 1 drachm of a thin fluid oil, and 1 ounce of a thick, tenacious, ponderous, pitchy oil, which stuck in the neck of the retort; the residuum weighed 42 ounces 7 drachms. The distilled liquors gave marks rather of an urinous and ammoniacal character, changing syrup of violets greenish, and emitting an urinous odour on the admixture of fixed alkaline salts or quicklime. The oil arose in yellow fumes, and smelled considerably sulphureous; it somewhat stained polished silver, but the stains were easily rubbed off. That which distilled at first was light, and swam on water; the succeeding parcels proved more and more gross and ponderous, and at last sank.”

Genssane, in 1770, published a detailed and interesting account of the mode in which pit-coal was distilled at iron-works at Sulzbach. His description was founded on personal observation. The distilling apparatus consisted of a chamber or large muffle of refractory clay, heated by a fireplace on each side. There were two openings in front provided with doors, an upper one through which the coal was charged, and a lower one through which the coke was withdrawn. The sides of the chamber were vertical, and the roof was arched. The bed was flat, and sloped downwards towards the back, in the bottom of which was a pipe communicating with a receiver on the outside. In this pipe was fixed another vertical pipe for the exit of the uncondensable products. There were not less than nine of these furnaces built together in a row, and at least three

were in operation, while three others were cooling. When the coal was half coked in the first three, three others were lighted, and so on in succession. As the coking generally lasted three days, the coke was withdrawn daily from three furnaces, and the three others were charged. The coal lost in coking an eighth of its weight.

The charge for each furnace was about a ton of raw coal, and somewhat less than half this weight of coal was required to distil a charge. The coke was used to smelt iron. Genssane made the following remarks : " Coal thus coked (*cuit*) exhales not the slightest odour in burning, and it has the advantage of lasting twice as long in the fire as wood-charcoal, instead of which it may be used for all purposes without fear of the least inconvenience. This is not all ; the oil and bitumens obtained in this operation almost pay the expenses of it. These two matters are thus turned to account. They collect together in the great receiver ; the mixture is poured into a large tub, and stirred during a long time with wooden instruments worked by hand ; by this manipulation the oil collects on the top, and is taken off with iron spoons, while the bitumen falls to the bottom of the tub ; this is sometimes sufficiently pure to be at once sent into the market ; but more frequently it is surcharged with water ; it is then boiled in a copper until the water is evaporated, and it deposits a pulpy matter, which is thrown away. After this the pure bitumen becomes very greasy and liquid, and it is in no respect inferior to the best grease for carriages. There is no difference between this oil of coal and that distilled from petroleum, except that the latter is much more inflammable and suddenly catches fire ; and it may be usefully employed in lamps by people in the country. No other light is used in the mines of Sulzbach, but it smokes much, and exhales a tolerably strong smell of bitumen."

The history of the process of coking at the ironworks at Sulzbach is interesting from another point of view, as showing how completely a great practical discovery may obtrude itself, as it were, upon the attention of men, and yet be unperceived. The chamber in which the coal was distilled was essentially a gas retort, and the gas which issued in a continuous current from the vertical pipe at the back, must often have taken fire

and produced a luminous flame ; but the idea of applying that gas to the purpose of lighting seems never to have occurred to those who observed it. Large gasworks were daily in operation at Sulzbach, and yet the merit of the invention of lighting by coal-gas was reserved for Murdoch in 1792, or more than twenty years afterwards.

From this time onwards some attention was given to the distillation of oil from coal, and in 1781 the Earl of Dundonald embodied in a patent specification a claim for condensing " the less coercible part of the vapour that comes off in distillation by commixing it with the steam of boiling water, and complete the condensation by the means of cold water—I also cause the vapour to pass through more condensing vessels than one, and separate by that means the different oils and substances according to the different degrees of coal and moisture requisite to condense."

In 1852, a patent was taken out by W. E. Newton for " the adaptation of ordinary coke ovens of an apparatus whereby the gaseous products evolved during the combustion of coal therein may, without interfering with the ordinary process of coking, be drawn off and conveyed away to a receptacle or chamber where they may be separated from each other, and combined with other chemical agents to form valuable products, or used for some other useful purpose." Ammoniacal compounds are particularly mentioned as being among the condensable products ; while the residual combustible gases are conducted under steam boilers or any other apparatus, where they are burned by the admission of air.

Seven years later, Edward Jones, of Russell's Hall Ironworks, near Dudley, secured a patent for collecting and condensing mainly or wholly the tar or other condensable volatile products given off during the process of coking in open fires or heaps. The fires were constructed in the usual manner with a central chimney. The bottom of the chimney was connected with an underground flue, which communicated with an old steam-boiler containing coke, and having a tap at the bottom ; and the boiler in its turn communicated with a chimney. A series of coke-fires were put in connection with the underground flue. Before or soon after igniting the coke heap, the top of the

central chimney is closed by a damper. The volatile products then pass downwards through the underground flue, and such as are condensable accumulate in the boiler, from which they are drawn off by the tap at the bottom. A considerable quantity of tar and other matters were thus obtained. The yield and quality of coke made was stated to have been not inferior to the ordinary method of coking in circular piles.

The distillation of oil from coal was, however, not prosecuted further as a definite industry, attention being solely directed to the provision of coke and of illuminating gas, satisfying industrial, manufacturing and domestic requirements on a large scale.

CHAPTER IV

THE DISTILLATION OF COAL

So numerous have been the early attempts to distil oil and other products from coal, that it is impossible to include them in this short treatise. Some idea has, however, been given of the extent of these efforts and further reference will also be found in the section dealing with the carbonization of coal, in which early records on the authority of Dr. Percy are included. Both in this country and on the continent the great value of the volatile constituents of coal were recognized certainly three centuries ago, but the work of distilling these from the mineral appears to have been undertaken in more or less of a dilettante spirit. They, however, were links in the chain which led up to the ultimate aim of converting these products to commercial use, and without which the achievements which have been and are chronicled in this brief work would have been made much more difficult. It was no less than one hundred years ago since Murdoch lighted upon the idea of utilizing the gases obtainable from coal, when the Honble. Robert Boyle carried out experiments on the distillation of coal and obtained therefrom a gas, being the first investigator to separate an illuminating agent from that material. It is remarkable that this discovery should have lain dormant so long, but the value of it in that early period was unrecognized. In addition to the references already made in this connection, it is interesting to note that in 1812 Lewette introduced an apparatus for the extraction of tar from coal. For this purpose two circular furnaces placed at each end of the apparatus with a fan or blasts to activate the fires were employed. The condensing apparatus between the furnaces consisted of a series of narrow passages in brick work, with a reservoir placed in the centre and front of the apparatus to receive the bitumen. The mode of operation was to place $3\frac{1}{2}$ tons of coal in one furnace, the connection with the other furnace being shut off by the register. The coals were kindled by lighting some kindling placed below the coal in the hearth and by opening the

blasts. In two hours, combustion became active, and the tar commenced to distil over. Combustion lasted twenty-four hours, and when completed, the register of the furnace was shut and the opposite one lighted. Thus the condensers were kept in constant use by alternate fires. By this method the coal yielded 10 per cent of tar and the residual coke was valuable for forges and iron furnace operations.

In 1824 Prosper and Charles Chervan invented a process for extracting by distillation the bitumen which the rocks of the Department of Saone and Loire contain. Cylindrical iron retorts were used 5 feet 2 inches long, 20 inches wide, and about $1\frac{1}{4}$ inches thick. From the bitumen was obtained an oil of the character of naphtha, and it was recommended for giving light in alcohol lamps. These inventors also extracted volatile oils in the proportion of 40 parts of oil to 100 parts of shale.

In the year 1833 Dr. Bley distilled brown coal, and obtained a small quantity of volatile oils in addition to ammoniacal products. Wagenmann carried out a large number of experiments in these directions with the object of obtaining a larger yield of tar. The results of these efforts were that from brown coal of a specific gravity of 1.369 yielding 29.37 per cent of water and 7.018 of ash, he obtained in 100 parts of coal : Coke, 37.66; ammonia, equal to 36.69 lb. per ton; tar, 5.96, and gas and steam, 19.96. From a brown coal of 1.252 specific gravity and with 39.58 per cent water and 3.43 ash, he obtained 30.43 of coke, 48.41 lb. per ton, of ammonia, 4.02 of tar, and 17.7 gas and steam.

Even in these early days, the shales of Dorsetshire attracted attention, and a distillation of samples of this by the same authority gave 9 per cent of tar, of a specific gravity of .910; creosote oil, 6 per cent of specific gravity 850 to 900, and of crude paraffin, 1/30th.

As time goes on it is clearly apparent from the wording not only of patent specifications but also of the records and experiments carried out, that the possibilities of coal distillation were realized, and that the conditions under which this distillation should be carried out were also from a chemical point of view pretty clearly grasped. In a work on this subject written in

1865 by A. Gesner,¹ he remarks that "in proper retorts the oils will all distil over at a temperature of 750° F. or 400° C., which is now the temperature proved to be the most efficient from the oil-production point of view and the non-production of permanent gases. A high degree of heat produces permanent gases from any volatile matter that may remain in the charge."

He also remarks that "if a quantity of coal be distilled in a retort or closed vessel at a heat of 1,200° F. or thereabouts, in the manner the coal gas is made, a large quantity of gas will be formed. The oily products will be small in quantity, and consist chiefly of benzol, naphtha, naphthalin, carbolic acid, and other hydro carbons, which so far as the oil manufacturer's objects are concerned may be called impurities. Again, the crude oils obtained by such a heat contain more carbon than those produced at a lower heat, much of the hydrogen being drawn off from the coal in carburetted gases. But if the heat to which the coals are exposed does not exceed 750 to 800° F. a different class of results follows."

Instead of true benzol the naphthalin will be replaced by paraffin, the carbolic acid will be less in quantity, and there will be a great increase of the oils employed in lamps and for oiling machinery. To obtain these results will depend upon the form of retort. The essential thing is to obtain an equal distribution of heat, and for this purpose revolving retorts were introduced. Horizontal retorts were also employed, and these were from 30 to 45 inches in width and from 8 to 10 feet in length. The latter was capable of distilling three charges of channel coal of 450 lb. each in 24 hours, at a heat not exceeding 780° F. The gas from the retorts was discharged into one main, from whence it was conveyed to a gas meter, to be subsequently used for fuel or for lighting.

In 1853, two patents were taken out in England for upright smoking furnaces, the object being to obtain crude oils and not coke. In this and other instances the coal was placed in large perpendicular cones of masonry. The fire was lighted below, and as it advanced upwards the volatile parts of the material were driven off by the heat produced by itself and without the

¹ *Practical Treatise on Coal, Petroleum, and Other Distilled Oils*, 1865.

aid of any external heat. The discharge pipes were fixed at the top of the furnace, and communicated with the condenser in which the oils were formed. The weakness of admitting air was obviated by driving a blast of air through the fire.

At the present time the distillation of coal for obtaining chiefly oil, is carried out on a commercial scale at the Messel works, in Germany. These works, known as the *Gewerkschaft Müssel*, are situated near Darmstadt, where the local coal is distilled. The process which is adopted for this purpose is divided into three stages, namely, the drying of the coal, in connection with the generation of steam; the distillation of the dried material; and the gasification of the residual coke with the steam generated in the first stage. The three stages are effected in the same retort, and in succession from above downward. The charging and discharging proceed continuously. No special mechanical devices are used to separate the various stages, this being satisfactorily accomplished by the manner in which the steam circulation is maintained. In correspondence with the three stages inside the retort, the external heating of same is effected in three zones, namely, a zone of maximum temperature for the production of water gas, in the lowermost portion of the retort; a middle zone, in which the distillation temperature prevails; and the upper zone, which is devoted to the generation of steam, i.e. the driving of the charge. The heating chambers are comparatively spacious, but, nevertheless, the only communication between them is by means of openings, of such small diameter as to preclude any convection of the heating gases from one chamber, or zone, to another; whilst only so much ascends from one space to another as is requisite for the amount of fumes generated at the actual draught. Owing to the roominess of the chambers, the convection therein is ample, and in each zone there is attained a uniform temperature which differs considerably from that of the preceding zone. Large quantities of heat are naturally required to expel the high percentage of moisture in the coal, and consequently the fumes must enter the steam-generating chamber at a very intense heat. As a matter of fact, the temperature is so high that the operation would not stop at the expulsion of moisture, but would also

affect the distillation of the dried material, were it not that care is taken to keep the temperature down to below that required for distillation, in the upper charging stage, by maintaining a very brisk circulation of steam in this stage. This steam, at a temperature of slightly above $100^{\circ}\text{C}.$, enters at the hottest part, and, itself becoming superheated, carries the excess of heat away to the place where the newly introduced coal, with all its original percentage of moisture, is situated. The circulation is produced by means of a powerful fan mounted on the retort, and is so efficacious that the steam remains free from any dry distillation products and can be led away for the production of water gas without causing any decomposition of valuable constituents. On the other hand, the utilization of the heat is so complete that the fumes escape into the chimney at a temperature of only $200^{\circ}\text{C}.$

The steam, which has greatly increased in quantity through the moisture absorbed during the circulation, is forced by a small blower into the bottom end of the retorts and ascends therein, forming water gas as it rises. The retorts are heated by the very large quantity of mixed water gas and distillation gas formed, amounting to over 500 cub. ft. per cwt. of coal in the charge, after all the condensable and extractable constituents in the gas have been removed. Even after the requirements of the retorts have been satisfied, there remains a considerable excess of gas, which is led away to the power station and utilized for steam-raising there. The calorific value of the gas is very high, and after elimination of the circa 10 per cent of carbon dioxide present, it is admirably adapted for incandescent lighting. The distillation vapours and water gas are drawn off through a common exhaust pipe about one-third of the way up the retort. The mixture is first freed from particles of water vapour, and then passed in succession through the ammonia-recovery plant, the condenser plant and oil washery, to a gasholder for delivery to the several centres of consumption. The portion destined for the gas engines is passed through purifiers charged with the usual ferric-hydroxide purifying mass, for the purpose of eliminating the contained sulphuretted hydrogen. The plant for treating the vapours before they reach the gasholder is more fully described later.

The following points in connection with the raw material may be mentioned here: the coal coming from the pit is crushed in a breaker and separated from dust and slack on special screens, since these finer portions would present an excessive resistance to the passage of steam in the retorts. The dust and slack are utilized in other ways by the aid of special appliances. Screens of perforated sheet iron were formerly used, but were afterwards discarded because they are liable to become obstructed in consequence of the clayey nature of the material, especially in wet weather. At present all the screens used are provided with rotary knives, projecting through the slits and keeping the latter clear of obstructions. The coal, reduced to lumps between a hen's egg and a goose egg in size, and classified, is transported by means of ordinary conveyors to the charging hopper of each retort. The retorts are emptied by means of a suitable discharging device which is set in operation for a short time every half-hour. The discharged residue can be perfectly pure ash, which is grey in colour—in contrast with the red ash furnished when the coal is burned in a grate—but turns red on calcination. In practice, however, this complete incineration is unnecessary, more gas being already produced than is required; and therefore, in the absence of any means of utilizing the surplus gas for the present, the residue is withdrawn with a carbon content of about 8 per cent, and removed to the spoil heap.

Twenty-four retorts of small sectional dimensions constitute a battery, capable of treating 26 tons in twenty-four hours. Charging and discharging proceed continuously.

The ammonia is recovered from the gaseous mixture by being scrubbed with dilute sulphuric acid, in towers of the Glover type. The tar obtained is of a greenish-brown colour and has a specific gravity of .855 to .860. Distillation is conducted in a partial vacuum and is facilitated by the action of stirrers. The thick residue is drawn off into retorts into which it is distilled to a cokey residue. These retorts alone need to be cooled down considerably for the purpose of entering them and removing the incrustated contents, the other stills being worked continuously. Tubular condensers, each provided with two receivers, are used. The partial vacuum is maintained

by means of side-valve air pumps, fitted with mercury gauges for measuring the vacuum produced. The stills and retorts are chiefly heated by burning the acid and alkali tar from the mixing plant.

The distillates from the residue retorts are united with tars and decomposed into a light and a heavy fraction, the former amounting to 16 per cent and the latter to 76 per cent. After chemical treatment, the first fraction is re-distilled, and furnishes, on the one hand, naphtha and crude lamp oil, and on the other, gas oil. The heavy fraction represents paraffin mass, and after chemical treatment is re-distilled. This process yields a small proportion of light oil, which is used direct as gas oil.

There is no separation of the heavy portion into soft and hard paraffin masses, the two being collected together and crystallized by cooling. The cooled mass is filtered in a press, and the press oil is collected, cooled down to -2° C. and filtered again. The last filtrate is either direct for gas oil, or occasionally worked up into lubricating oil. The lamp oil is treated to bring the colour and smell to a high state of perfection; but in spite of its low density (0.800) has such a high viscosity and low capillarity when burned in lamps that it cannot nowadays compete with ordinary petroleum.¹

¹ *Shale Oils and Tars*, by Dr. W. Scheithauer.

CHAPTER V

THE BY-PRODUCT COKE OVEN

WITH the relinquishment of the use of charcoal, the first attempts at carbonizing coal followed on the lines then in vogue for the treatment of wood, the mineral being burnt in large heaps. The first structure employed for the purpose was made in the form of these, and were subsequently termed beehive ovens, on account of the similarity of their shape to the beehive. This type of oven was, until recent years, most widely adopted in this country. In Germany, Belgium and America, the by-product recovery oven is most generally employed, and although in the modern type of beehive the recovery of some of the volatile constituents is carried out, the coke is regarded as of the very first importance, and it is asserted erroneously by some authorities that a better quality coke is obtained than in the ovens where much greater attention is paid to the by-products. It is unnecessary here to give a detailed description of this type of oven, as in its original form its function was merely to provide coke, the valuable volatile constituents of the coal being disregarded. It may, however, be mentioned that the yield of these ovens, usually slack containing 30 per cent of volatile matter, ranged from 58 to 60 per cent, showing a loss of from 10 to 14 per cent, by the admission of air to the coking chamber. The average charge was about 7 tons, and from 86 to 94 hours were required to complete the operation. The principle underlying the manufacture of coke differs essentially from that adopted in the manufacture of illuminating gas. In the former, large charges subjected to long periods of heating are regarded as necessary for the production of a good, metallurgical coke, while where large quantities of gas are required, small charges, rapidly carbonized, are adopted.

The transition from the old beehive to the modern product recovery oven was a slow process, and many forms were introduced and abandoned before the advent of the Coppee oven in the year 1861, while the Appolt oven was in use in France in

857. Both these types of ovens were distinct advances on the older type, the chief improvement lying in the fact that they were externally fired, the heat for carbonizing being largely obtained from the combustion of the gas. They were of rectangular shape, the Coppee being about 30 feet long and 3 ft. 6 ins. high, tapering slightly from one end to the other. Both of these ovens were fed from the top, and the advantages derived were increased yield, shorter coking period, more efficient means of utilizing the gases, saving in heat by external quenching, and economy of time and labour.

We now reach the period of the by-product recovery ovens.

The first of these to be introduced into this country was the Simon Carves oven, a battery of six ovens being erected about 1869.

In this oven the gases are drawn off by means of an exhauster, and passing through the by-product plant return to the distributing main. From this main, through a service pipe to each oven, the gas is fed above a fire-grate beneath the floor of the oven, where a supply of air, pre-heated to about 800° F. (425° C.), is admitted. Combustion then takes place, and the products pass along the sole flue, into the top side flue, and thence to the recuperative system of flues. The waste gases from alternative ovens pass to a chimney at one end of the battery, whilst the waste heat from other ovens is extracted by a chimney at the opposite end of the battery. The air flues are sandwiched between these two flues.

The next development occurred by the introduction of the Semet-Solvay oven (Fig. 1), which is somewhat similar in principle to that first described. Some of the ovens in use have three flues at each side, but the practice now is to supply four or five side flues. The greater height of these is of course an advantage, as modern compressing machinery is capable of charging an oven of larger dimensions as readily as a small one, while no greater space is occupied thereby. In the Standard type of Semet-Solvay-Piette oven, the side flues are entirely independent of the superstructure, the weight being carried on separate pillars. In addition to greatly strengthening the oven, these pillars act as a reservoir of heat, which is an advantage during temporary stoppages of the plant. This heat also aids in

counteracting the cooling of the flues induced by the introduction of a charge of wet slack. The heat of this oven is very easily regulated in consequence of the fact that each oven is built independently, and has two series of side flues common to two adjoining ovens. Another advantage is that the flues are constructed of small rectangular blocks, measuring about $8 \times 4 \times 2$ in., which precludes gas leakage. The gases from the coking chamber are passed through the by-product plant and return to the distributing main from which it is

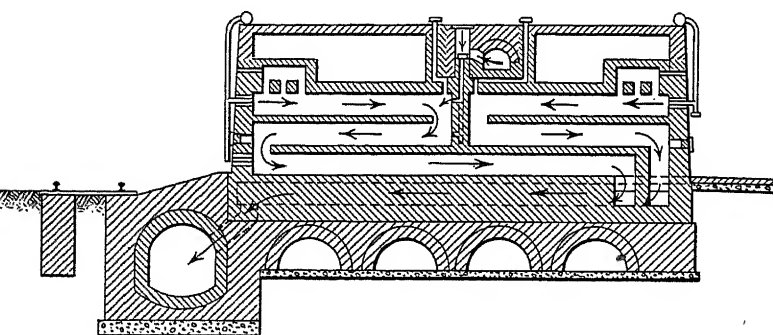


FIG. 1.—THE SEMET-SOLVAY-PIETTE COKE OVEN
(Sectional View)

fed into the flues. The air for combustion is heated to about 300°C ., but the later type of generator having a continuous action, avoids the sudden changes of temperature during the periodical reversing which is characteristic of the ordinary type of regenerator. The heats obtained from the different flues are shown in the following table—

Top Side Flue	.	.	.	.	$1,190^{\circ}\text{C}$.
Middle Side Flue	.	.	.	.	$1,200^{\circ}\text{C}$.
Bottom Side Flue	.	.	.	.	$1,170^{\circ}\text{C}$.
Sole Flue	.	.	.	.	$1,100^{\circ}\text{C}$.

The charges for this oven are compressed before they are inserted in the oven, and are carried out by machinery. The quantity of spare gas in the ordinary type is stated to be about 30 per cent, and with continuous regenerators about 50 per cent.

The late Sir Lowthian Bell, in a paper read before the Iron and Steel Institute in 1904, gave some interesting particulars in regard to the Huessener coke oven, which is of the horizontal

due type. In this oven the air for combustion is not preheated, and the heats obtained in the flues are stated by this authority to be: the bottom side flue $1,037^{\circ}$ C., and the top side flue $1,205^{\circ}$ C. The spare gas amounted to 30 per cent of the gas generated, and the waste heat under boilers evaporated 24 cwt. of water per ton of coal treated.

The Otto-Hoffman coke oven is heated by vertical flues, though there is no direct communication between the interior of the oven and the side flues under normal conditions. The gases generated are conducted through the by-product plant before being admitted to the side flues. The air necessary for combustion is preheated to a good heat in regenerators.

The latest form of the Otto-Hilgenstock was a distinct advance on the oven just described, and is constructed in two types, namely, the "waste heat" type and "live gas" type. Both forms are characterized by the vertical flue, but the distribution of the heat has been greatly improved. The gases from the oven chamber are conducted through the by-product plant. After the by-products have been removed, the gas is led into a series of nozzles or bunsen burners. In the case of the "waste heat" oven, the action of the latter draws in sufficient air, previously heated in its passage to the flues, for the combustion. In the "regenerative" type, the air is preheated by passing through the regenerators, and is subsequently led under the sole of the oven to the combustion chambers. In both instances, instead of passing into one combustion chamber, the gas is subdivided, being fed into the vertical flues in as many as fifteen or sixteen places. Each burner, therefore, is required to heat only a small portion of the oven walls, and, as the air and gas supply are perfectly under control, sooting of the flues is usually avoided, and the life of the oven walls is prolonged considerably.

The gas ignites at the level of the coking chamber, and rises vertically through the heating flues, following its natural tendency. The chimney draught is thus decreased, and the loss of gas, through leakages from the oven chamber to the side flues, is reduced to a minimum. In the "waste heat" type, the amount of spare gas is 20 to 40 per cent, but by using regenerators the amount of spare gas is increased to 50 per

662.62

1383

N251

cent. The ovens may be charged by tubs from the top, but the usual plan is to use compressing machinery. By using the latest type of ammonia recovery plant, the amount of steam required for the actual working of the plant is considerably reduced, and the steam available for outside purposes correspondingly increased.

In the latest type of Simon Carves oven, entire control over the supply of air and gas is obtained, and this regulation can be readily and easily effected, all cocks and dampers being operated from the outside.

The Koppers is another vertical flue oven, and is built in two types—"waste heat" and "regenerative." The waste heat oven is of very simple construction, and after being deprived of its by-products, the gas is fed from the distributing main into the gas-distributing channel, formed of firebrick pipes. It passes from this channel through orifices, each fitted with a gas-nozzle, into the vertical flues, which number from 30 to 35, each having a separate nozzle. The nozzles have oval-shaped orifices, and may be very easily changed. The quantity of gas passing into each flue may be perfectly adjusted by means of these nozzles. The air necessary for combustion is drawn in by the chimney draught through the air distributing channel from the air conduit, and the amount of air can be controlled by the damper arrangement. The combustion of gas in the flues can be readily controlled by the dampers and gas nozzles, and an exceedingly high state of efficiency maintained.

In the regenerative type, each oven has an entirely separate regenerator, which permits of repairs to individual ovens without affecting the others. The reversing of the gas and air may be done simultaneously along the whole of the battery. The waste heat is more than sufficient to maintain the heat in the regenerators, therefore arrangements are made for leading off a portion of the products of combustion through the flues. The quantity of spare gas from ovens of the "waste heat" type varies from 15 to 20 per cent, with regenerators the amount is from 50 to 60 per cent of the total gas evolved.

The latest form of Coppee oven, similar to the preceding oven, is constructed for by product recovery, and is designed in two types (Fig. 1B). In the regenerative type, the regenerators

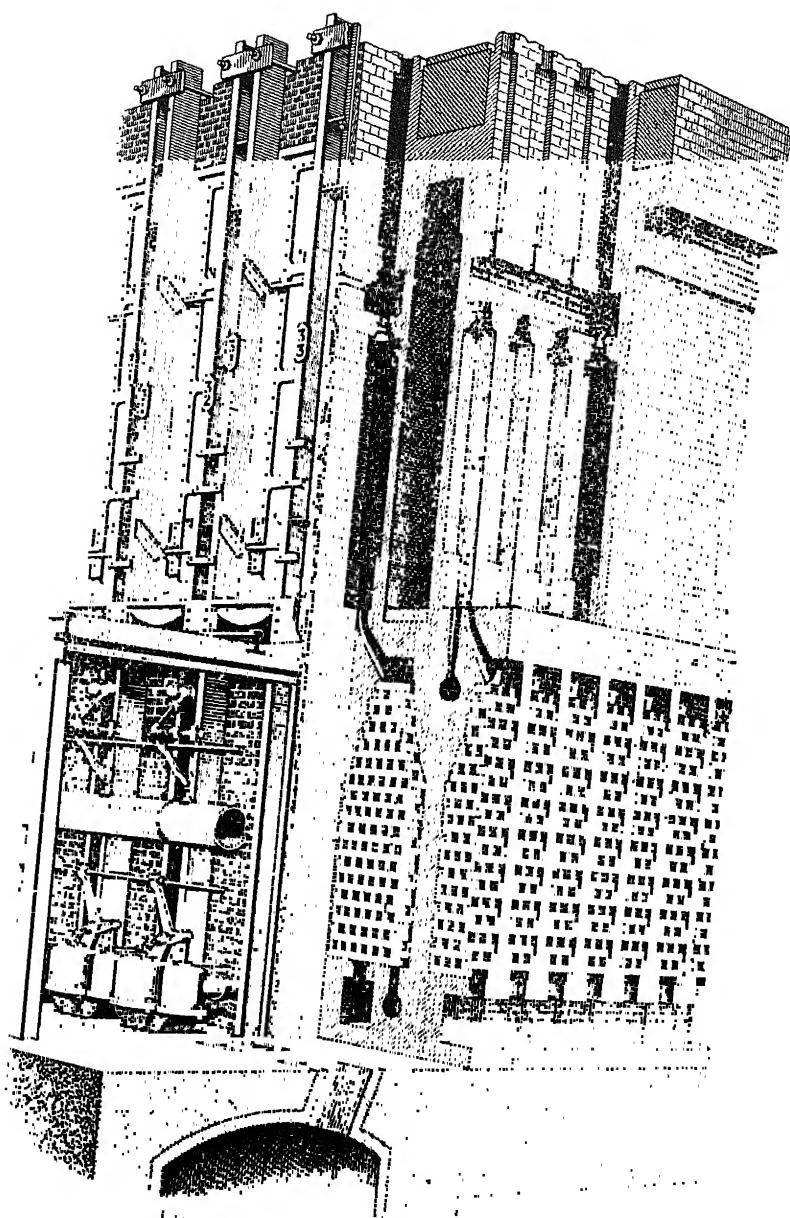


FIG. 1A.—THE COPPEE COKE OVEN

are situated underneath the ovens, one being connected to the sole flue of the odd-numbered ovens, the other to the even-numbered ovens. The series of vertical side flues is divided into five sections, each consisting of six flues. The gas is fed into the flues by means of tubes, two at the front and two at the back, each pair feeding three flues. The air, heated to a temperature of about $1,000^{\circ}\text{C.}$, enters by the sole flue 2, and meets the gas at the foot of the vertical flues. The heated waste products pass down 4, 5 and 6, to the sole flues 1 and 2, etc., thence through the corresponding regenerator to the chimney. The direction is then reversed. The reversing of the air current, therefore, affects only three flues at a time, the flues for the gases descending are almost as hot as the ascension flues, and a uniform temperature is maintained throughout the length of the oven wall.

The Collin oven is of the vertical flued type, with or without regenerators. The principal feature of this type of oven is the introduction of a series of flues with intersecting bond stones, which are hollow. In the case of the regenerative type, the flues thus formed serve two purposes: To lead off the waste gases after combustion in the vertical flues, and to conduct hot air from the generators to the gas from the upper distributing channels during another period of the coking process. The sectional area of these inner flues has been so arranged as to provide the correct proportions of gas and air.

The temperature attained in coke ovens ranges as a rule from about $1,100^{\circ}$ to $1,300^{\circ}\text{C.}$, varying in the different flues. In the Simon Carves oven, the air is heated in the recuperator to from 430° to 480°C. , while the temperature in the various flues is distributed as follows: Top flue, $1,130^{\circ}$ to $1,180^{\circ}$; second flue, $1,260^{\circ}$ to $1,278^{\circ}$; third flue, $1,100^{\circ}$ to $1,120^{\circ}$; and the lowest side flue, $1,125^{\circ}$ to $1,130^{\circ}$, while in the flues below the oven sole the temperature is from $1,540^{\circ}$ to $1,565^{\circ}\text{C.}$ From this type of oven the yield of coke is stated to be 77 per cent, when using Durham coal, 69 per cent in Accrington, and 52 per cent in Staffordshire. The ammonia expressed in sulphate amounted to 1.25 per cent with North country coal, and about 2 per cent with Staffordshire coal. The yield of tar varies from 3 to 4 per cent with a specific gravity of 1.1.

In the Otto-Hilgenstock ovens, in which Bunsen burners are employed, the temperature rises as high as from $1,300^{\circ}$ to $1,400^{\circ}$ C.

The by-product ovens of the Coppee type yield a tar which is at least equal in value to the ordinary gas tar, though in contrast to this, the tar from the former contains much less creosote oil and hard pitch than anthracene oil, which is rather an advantage than otherwise. The ovens of the beehive type modified by the use of external heat and recuperators working at a lower temperature than those just referred to, yield a somewhat inferior tar; the benzol containing very little benzene, less naphtha, and much less anthracene. An interesting table given by Dr. Lunge, comparing the results obtained in the Semet-Solvay ovens and the beehive ovens at Syracuse, N.Y., shows the comparative work carried out by these two types—

	Semet-Solvay	Beehive.
Number of ovens	12	12
Average time of coking	20 hours	51 hours
No. of furnaces discharged in 24 hours	14.4	5.5
Coal coked in 24 hours	71,688 kgs.	27,760 kgs.
Coke produced	57,699 kgs.	17,327 kgs.
Sulphate of ammonia produced in 24 hours	772 kgs.	Nil
Tar produced in 24 hours	2,651 kgs.	"
Yield of coke, per cent	80.7	62.3
Yield of ammonia sulphate per cent	1.075	Nil
Yield of tar per cent	3.69	"

Dr. Scheithauer also gives the following interesting comparison showing the difference between the coke oven tar and gas tar, in their yield of various products—

FRACTIONS.	COKE OVEN TAR.		GAS TAR.		
	Dominion Coal.	Westphalian Coal.	German.	American.	
				Good.	Bad.
	%	%	%	%	%
Light Oil	1.26	6.55	2.5	1.65	6.14
Middle Oil	14.73	10.54	2.5	10.66	5.03
Heavy Oil	7.07	7.62	25.0	8.18	7.50
Anthracene Oil	21.38	44.35	10.0	14.05	11.71
Pitch	53.63	30.35	60.0	61.16	68.25
Water	1.52	trace	—	1.81	—

It is manifest from this brief review of the evolution of the modern coke oven, that the great value and necessity of securing as large a proportion of the volatile constituents of coal as possible has been very practically recognized. It is also admitted by most authorities that there still remain untouched possibilities in the direction of improvement, and in conserving and utilizing a larger proportion of the volatile gases given off during the attainment of the main object, namely, the manufacture of a good metallurgical coke. The very fact that such a diversity of practice exists even at the present time, and that one apparatus differs from another in certain important particulars, suggests that the most satisfactory and most profitable methods of obtaining, in fullest measure, those ultra-valuable products which coal has been shown to possess have not yet been fully developed.

For instance, some considerable period of experimentation elapsed before it was admitted that the vertical retort yielded superior results to the horizontal, that is, if the high temperatures now employed are essential to the end in view. This question of temperature is, after all, the most vital to be considered, because it is fundamental, and we are apparently again at the parting of the ways thereon.

Professor Lewes crystallizes the problem in a few words. He remarks: "We make elaborate tables of the composition of gases and tars, produced at various distillation temperatures, but the only information that they give us is what is left undecomposed under unknown and varying conditions, the only certain factors being that the heat was nowhere above that which we are pleased to call the temperature of distillation."

From the point of view, also, of the value of coke itself, the fact is coming to be recognized in Germany, asserts the same authority, that even for the heating of the furnace the coke made at extreme temperatures is not as good as when the heats were slightly lower. In America there is slight trend of opinion in the same direction, and Messrs. Parr and Olin and others have shown that by the carbonization of coal at relatively lower temperatures, a coke of good quality and strength may be obtained. Practice has, therefore, led towards this end: the dissociation of the non-volatile and volatile constituents

of coal in such manner as will conserve these constituents in the largest proportions and in the highest qualities.

American Practice.

The results of American gas works and coke oven practice in connection with the recovery of tar, are referred to by W. W. Odell.¹ Tar from inclined retorts does not differ widely in this respect from the product of horizontal retorts, the free carbon content being 12 to 20 per cent. Although it may be said, in general, that these tars have much the same constituents, but in varying proportions, it is to be noted that the horizontal-retort tar with a high specific gravity and high free-carbon content, yields an appreciably greater percentage of pitch and hydrocarbons having a high boiling point. Tar obtained by carbonizing coal at low temperatures differs considerably from ordinary retort tar in both chemical and physical properties, and is in some respects much like a mineral oil, although its acid content is very high. So far as the authors know, this kind of tar is not being produced commercially in large quantities, and is mentioned here merely to point out the effect of the temperature of carbonizing on the resulting tar.

Differences between the various tars are in great measure due to the rate, duration, and completeness of heating of the coal, the amount of exposure of the tarry vapours to hot brick or coke surfaces, the temperature of these walls, and the exposure of the vapour to the final temperatures reached in the coking chamber. All of these particulars are considered in the design of chambers or retorts for coking coal. Euchene's experiments in carbonizing coal in horizontal retorts have shown that a large proportion of the tar produced comes over in the early stages of carbonization. His results, given in the following table, were obtained when the final average temperature in the carbonized fuel was 950° C. (1,724° F.). Considering the rate of decomposition of the coal to be proportional to the totals given in the table, the amounts decomposed from the first to the last hour are approximately represented by the figures, 40, 30, 20, and 11. The tar produced is not proportional

¹ *Preparation and Uses of Tar and its Simple Crude Derivatives*, by W. W. Odell, U.S. Bureau of Mines.

to these figures, for the reason that during the later stages of carbonizing, the tar formed in the inner zone of coal has to pass through a zone of hot coke, where much of it is decomposed. Thus one can see that the size and shape of the retort and the manner of removing the gas—which affect decomposition—affect the yield and quality of tar.

TABLE I
TAR, WATER, AND GAS PRODUCED DURING CARBONIZATION

PRODUCTS.	First Hour.	Second Hour.	Third Hour.	Fourth Hour.	TOTAL.
Gas	17.3	16.6	14.3	9.5	57.7
Water	12.3	7.3	2.9	1.0	23.5
Tar	10.1	5.3	2.8	.6	18.8
TOTAL	39.7	29.2	20.0	11.1	100.0

The vertical retort tar is thinner, has a lower specific gravity, and contains less free carbon, and more tar acids than the tar from horizontal retorts.

By-product oven tar is less viscous, is lighter in weight—that is, has a lower specific gravity, contains more oils, less pitch and less free carbon than the tar from horizontal retorts, and is in some respects much like the tar from vertical retorts. Table 2 shows the relative properties of the various coal tars—

TABLE II
PROPERTIES OF COAL TARs

PROPERTIES.	GAS WORKS COAL TAR.			COKE OVEN TARs.
	Horizontal Retorts.	Inclined Retorts.	Vertical Retorts.	
Specific gravity	1.20-1.25	1.10-1.20	1.10-1.15	1.17-1.22
Viscosity	High	Medium	Low	Low
¹ Free Carbon (insoluble in benzole), per cent	18-30	10-20	0.4-5	2-12
Distillate, per cent of volume on distilling to a medium grade of pitch	20-30	25-35	30-40	25-35
Per cent of pitch by volume (medium pitch) plus losses	70-80	65-75	60-70	65-75
Tar acids, per cent	1.6-3	3-5	7-8	0.4-2.5

¹ The so-called free carbon, which is a constituent in varying quantities of all tars, is not pure carbon, as the term might lead one to think, but consists of complex relatively insoluble carbon compounds containing approximately 94 to 95 per cent of carbon.

CHAPTER VI

FUEL RESEARCH BOARD EXPERIMENTS

EXPERIMENTS carried out by the Fuel Research Board deal with the distillation of coal in vertical retorts, though "the work is of a preliminary nature and does not profess to provide a solution of the problem of the economic low temperature carbonization of coal."

The experiments commenced with Ellistown Main coal with the combustion chamber temperatures between 800° and 1000° C. This, in view of latest developments, cannot be regarded as low temperature, and although what is known as high temperature is considerably above this, the character of the products obtainable vary to a very small extent, as between the two descriptions of temperature mentioned.

In the experiments referred to, the combustion chamber temperatures were gradually raised till at 950° C., the coke contained about 9 per cent of total volatiles, and when burned in an open grate gave quite satisfactory results.

With 2 per cent steam passing into the retorts, the following were the approximate yields obtained with a through-put of 15 tons of coal per retort per day—

YIELD PER TON OF COAL

Coke	.	.	.	.	.	.	14.2 cwt.
Gas	.	.	.	.	.	.	7,790 cu. ft. or 45 therms
Tar	.	.	.	.	.	.	13.3 gall.
Sulphate of ammonia	.	.	.	.	.	.	18.0 lb.

After this the carbonizing temperature was raised to 1,100° C., but though the coke made was stronger, it contained only 5 per cent of total volatile matter, and was found to be unsuitable as fuel for use in open grates.

At this stage it was decided to use for further experiments, Ellistown Main and Mitchell Main coals, a 50/50 mixture of which had been found very suitable for the manufacture of coke cakes in the horizontal retorts.

The results obtained with this mixture were as follows—

ASSAY.	Grms. per 100 (Dry).	Per ton of Coal (as charged).
Coke	75.55	14.2 cwt.
Gas	8.15	3,270 cu. ft.
Tar	11.25	23.8 gall.
Liquor	5.00	24.6 gall.
	<u>99.95</u>	
Sulphate of Ammonia (pure) .	0.08	6.6 lb.

TAR. The yield of dry tar obtained in each test is set out below for comparison along with its specific gravity and distillation range—

TEST No.	1	2	3	4
Steam, per cent	Nil	7.24	13.47	20.00
Yield, gallons per ton	12.72	14.18	15.22	16.62
Specific gravity at 15° C.	1.064	1.062	1.060	1.068
Calorific value, B.Th.U's.	16,790	16,580	16,630	16,460
Sulphur, per cent	0.50	0.35	0.34	0.20
Distillation per cent by weight—				
To 170° C.	7.0	7.2	6.9	6.2
170-230° C.	14.5	14.9	15.9	14.1
230-270° C.	15.3	15.1	14.2	13.4
270-310° C.	11.7	12.2	12.6	11.7
Pitch	51.4	50.4	49.8	54.5
Loss	0.1	0.2	0.6	0.1

The differences observable from the above distillation were very slight, so that only two of the tars were selected for further examination. The two selected were the extremes, Tests 1 and 4, and as the yield of tar had been increased by steaming from 12.72 galls. to 16.62 galls. or 30.6 per cent, it was expected that a more detailed examination would indicate some real differences. For the purpose of comparison the results given by a low temperature horizontal retort tar made from the same coal mixture are included in some of the tables.

The fractions obtained from tars 1 and 4 were specially examined, as follows—

The specific gravity of each was determined, and the amounts removable by refining with sulphuric acid and caustic soda. The boiling ranges of the refined fractions were then determined, and also those of the separated and washed tar acids. The fractions obtained from Test 1 tar were slightly higher in

sp.gr. than those from Test 4 tar, but those in turn were slightly higher than horizontal retort tar fractions.

The purifications of the fractions shows only small differences and these can best be followed from the tabulated results. These are shown in the table with a comparison of the distillation ranges and sp.gr.'s of the crude fractions.

The boiling ranges of the refined fractions are also shown comparatively, and the main differences found are shown below—

1. The light spirit from the 20 per cent steam test is slightly heavier.
2. The oil from the 20 per cent steam tar is slightly lighter in the case of all fractions.
3. The corresponding fractions from low temperature horizontal retort tar are in every case lighter. In fraction 3, the rate of distillation is slower up to $220^{\circ}\text{C}.$, but much higher from $220^{\circ}\text{C}.$ to $270^{\circ}\text{C}.$

The separated tar acids from each fraction were mixed proportionately, washed, and distilled. The distillation ranges are given in the table. The two vertical retort tars give very similar results, and both contain a higher proportion of low boiling point tar acids than the horizontal tar.

The yield of all these crude and refined fractions have been calculated per ton of mixed coal. The high yield of pitch from the 20 per cent steam test is noticeable.

In previous experiments carried out by the Fuel Research Board on different descriptions of coal, although at higher temperatures than those now obtaining in low temperature practice, it was found that the absolute gain of tar per ton of coal carbonized with 20 per cent of steam were for the Yorkshire coal 34 lb. and the Scottish 40 lb., and of sulphate of ammonia 6 lb. and 11 lb. respectively.

The Board has conducted a considerable number of tests and experiments and the above is included as illustrating the nature of the work engaged in. It should be pointed out, however, that the temperatures generally employed at the Board's station are not those from which the best results, as far as quantity and quality of the oil is concerned, may be obtained.

One important point is emphasized in the details given, namely, the increase in the yields of tar and the reduction of sulphur contents by the use of steam in distillation. On the other hand, the high temperatures employed were responsible for an excess of irreducible gas.

It is remarkable, indeed, that the Fuel Research Board should adhere to the use of such high temperatures, in view not only of latest practice and the products most valuable to this country, but of the experience gained nearly 60 years ago.

In a work by A. Gesner,¹ published in 1865, we find the following record of the distillation of cannel coal, at both high and low temperatures—

Temperature 1,200° C.			Temperature 371° C.-426° C.		
Coal gas, cu. ft.	.	7,450	Irreducible gas, cu. ft.	.	1,400
Tar oil, galls.	.	18½	Crude oil, galls.	.	68
Coke, lb.	.	1,200	Coke, lb.	.	1,280

The efficacy of really low temperature was thus, even at that early stage, clearly apparent, yet it is only within the last year or so that these conditions have been recognized and adopted, at any rate, in connection with the distillation of coal.

The latest tests carried out by the Fuel Research Board were in connection with a South Wales gas coal, selected from two seams of the Meiros Collieries, Llanharan. Admirably as the work was done and interesting as are the results they do not add anything to our previous knowledge. The temperature employed was so high that the principal product was gas, with the result that the yield of oil was very small. The solid residue, in quantity, was approximately the same as in what is now known as "low" temperature. It is curious that the Board, in view of the great need of this country of an oil supply, does not devote some attention to the temperatures at which this could be secured.

¹ *Practical Treatise on Coal, Petroleum, and other Distilled Oils.*

CHAPTER VII

MODERN PRACTICE IN LOW TEMPERATURE DISTILLATION

THE carbonization of coal for the purpose of obtaining oil, should be carried out at the lowest temperature possible, and a reasonable time should be allowed for the operation. Low temperature, slow heating and rapid removal of the volatile products favour the formation of proper hydrocarbons, but high temperature, rapid heating and a longer exposure of the volatile products to high temperature, tend to form unwanted acid hydrocarbons, phenols, benzol, etc., and to form irreducible gases. The large variety of retorts now presented to the public may be classified into two groups, viz.—

(a) Retorts heated externally—either vertical or horizontal. If horizontal, the shell is rigid, with a spiral or paddle propelling the material—or the shell itself revolves.

(b) Retorts with internal heating, either exclusively or combined with external heating.

HORIZONTAL RETORTS, such as—

Direct Fired Chiswick or Del Monte	}	Directly fired
Retort transformed into the Salerno		
Plauson Retort		
Gordon Multiple Retort		
Lamplough-Harper System	}	Heated by steam jacket, internal superheated steam
Day		

ROTARY RETORTS.

Spence	}	Externally directly fired
Fusion Corporation		
Randall		
„ (German)		
Nielsen	}	Heated by superheated gas (steam) internally
Dr. White		
Maclaurin		
Parker		
Universal		

VERTICAL.

1. Day-Heller	}	Metallurgical roasting furnace with internal heating, steam and gas
2. Hartman		
3. McDougall		
4. Ridge,		
5. Trent		
6. Wedge, etc.		

Exterior heating, subjecting the retort to direct fire, exposes the material to over-heating. To transmit to the fragments

of coal and other material the proper heat to develop and expel the oil vapour, it is necessary to heat the exterior of the retort to a high temperature, which will immediately affect the nature of the oil products obtained. At one time, too relatively prolonged high temperatures were employed, and the formation of a large amount of irreducible gas was the result. Many systems designed on these lines are effective in the production of oil, but the character of the oil obtained is of the aromatic description, yielding phenols, anthracene, etc., none of which is capable of supplying the ever increasing demand for motor spirit, paraffin oil, etc.

Recent practice has revealed the fact that temperatures must be kept as low as possible in order to secure the results desired. Formerly 500° C. was considered a reasonably low temperature, but it has now been demonstrated that oil can be distilled at 130° C., and complete extraction obtained at from 340° C. to 345° C., and that the oil produced is of a paraffinoid character, yielding light fractions of the benzene series. It has also been proved that approximately 1 gallon to 1½ gallons of oil are obtainable from 1 per cent of volatile matter in the coal.

Superheated Steam.

In view of the difficulty of transmitting low temperature heat through non-conductive materials, (coal, oil shale, etc., will not transmit an even temperature through more than 2 in. from the source of heat), attention has naturally been directed to the possibility of carrying the heat into the retort so that a more intimate contact could be obtained with the material within it. A simple means of conveying heat into the interior of a retort is by means of hot gases, but superheated steam is now regarded as the best and most economical means. Steam has a high specific heat and consequently a small amount will carry a great number of heat units. Steam has already been tried long ago, and was used in the old Scotch vertical retort, being purposely directed on the spent shales for improving the output of ammonia. The action of the superheated steam on the fresh shales in the upper region, improved the oil production. Some material hitherto yielding 90 to 100 gallons of oil per ton, reached 100 to 120 gallons of an oil of

better quality. There certainly can be no objection to the use of steam with oil as the condensation and separation of the water is nothing new. This method of using gas or steam superheated as a means of internal heating, is now being largely applied in various retorts, e.g. vertical retorts, the Universal retort, the Maclaurin, using gas only; horizontal retorts, or revolving kiln, the Nielsen, the Plauson, the horizontal fixed retort with external heating and superheated steam introduced internally, the D. T. Day, the Lamplough-Harper, and the Hartman. The Lamplough-Harper, although heated externally, does not allow direct contact of fire with the inner shell of the retort, which is surrounded by a steam jacket through which the steam is superheated, thus securing double advantage. Among the directly-heated retorts are the rotary kiln or roaster, such as is used by the Fusion Corporation, the Randall in America, and in Canada, and a German patent operated similarly. The retorts with fixed shell, having screws or paddles to move the material, include the old Chiswick or Del Monte, provided with agitating paddles and now known as the Salerni which is being experimented with in France, and the Gordon in America. The majority of these directly-heated retorts, although some of them are ingeniously arranged for a graduated temperature and the rapid elimination by sections of the vapours produced, are unavoidably overheated, cause a certain amount of cracking and develop an undue quantity of irreducible gases. A few attempts have been made in America to evolve a larger retort on the mechanical roasting furnace principle, claiming a throughput of 200 tons or more a day, but the heating of such an enormous appliance must be difficult. Even the best design employing superheated steam internally in addition to direct heating externally, produced the enormous quantity of 10,000 cubic feet of irreducible gases to the ton of shale treated. Much progress has been made recently, using temperature as low as 350° C., and extracting practically all the oil theoretically contained, but such results are only obtained with the system and appliances using superheated gas or steam internally, and such processes should be closely followed and carefully tried. One important point which has

Recently been developed, is the great importance of a careful condensation. Much depends on such condensation to influence the amount of saturated hydrocarbons obtained, and to reduce the volume of gases. The Lamplough-Harper condensing towers are very effective in this direction, but the White system and the Plauson have to be carefully followed. The system of internal heating with, or even without steam, is the system to be followed. It is the "Heat Exchanging system," and if a careful calculation is made of the fuel required for the distillation of one ton of coal or oil shale, etc., it will be seen that hardly more than half the thermal units of heat are required by using this system than would be required for external heating. The idea that there is only sufficient irreducible gas to carry the retorting is erroneous, and there really ought to be very little of such gas. The real fuel available for heating purposes is the spent shales, or coke, either burned directly or through gas producers, and used to heat the gases or steam which are carrying heat into the retorts. Even with systems using apparently only gas as the heat carrier, there is always enough moisture in any coal or shale, some of them being very rich in this respect. Such steam is introduced into the system, which in reality works on superheated steam.

Continental Practice.

The treatment of coal for oil on the Continent, that is, chiefly in Belgium, France and Germany, is practically limited to the collection of by-products from the manufacturing of industrial or metallurgical coke, and from the making of town gas. At the same time, there has recently been a move towards treating industrial coal by low temperature methods.

These industries have greatly improved their methods, and large quantities of oils and tar are now recovered. Unfortunately, the necessity of using high temperature for the obtaining of metallurgical coke has the effect of producing only oils of the benzol and phenol series and a high proportion of tar. These products, although very valuable, are not of such value as the oils obtained by low-temperature carbonization. France and Germany have for a long period treated their large deposits of lignites and shales with the object of obtaining

oils. In France there now exists a serious move on a more extensive scale in this direction, and an authoritative Government Commission has been appointed to investigate the various deposits of lignites and shales and the best methods of treating these according to their character and value. The Var Oil Company treating oil-shales and using a description of retort the outcome of the company's experiments, propose to work at a very low temperature, and, in an experimental plant, have produced excellent results. The company has also surmounted the difficulty of the tendency of the shales to stick and clog.

For bituminous lignites and shales there are several new retorts now being tried, but no definite reports are available.

In Germany (in Saxon-Thuringia), the treatment of lignites for oil is an old-established industry, and, as a matter of fact, it is the only oil activity of that area. The method employed is that adopted in the modern coke oven system, and built in groups of from ten to twenty ovens in blocks. The heating is done by burning the irreducible gas produced in the flues of the oven walls and under the floor. The working is intermittent, each oven taking about a 10 ton charge, and the operation, including loading and off-loading, occupying from 2 to $2\frac{1}{2}$ hours.

Great improvement has recently been achieved by the introduction of steam into the retorts, and the production of from 13 to 14 gallons of crude oil per ton has been increased to 18 gallons per ton. At the same time, the character of the oils obtained has been greatly improved. This system, however, although fairly successful and economical, is still working at a much too high a temperature, namely, about 500°C .

The amorphous coke obtained is in one case used directly in the gas producers to provide steam for a large electric generating station, while in another instance they are transforming their coke into very valuable briquettes of high calorific power.

The latest records show that a dozen works treating about 1 million tons of lignite are producing 60,000 tons of oils and 10,000 tons of paraffin (Montan Wax), while the coke obtained is of 12,500 B.T.U., from which briquettes of 14,000 B.T.U. are produced.

Such treatment, so highly advantageous, is tending gradually to replace the old German method of briquetting the raw

lignite direct, and it is a fact that such direct briquetting of raw lignite, although giving a very solid and easily handled fuel, increases the calorific power to a very slight extent, while the dangerous operation of drying the lignite before pressing involves a cost as high as the distillation.

America.

In America in 1915-16, Chas. Hoover, after elaborate experiments and research in connection with the laboratory of the Research Department of the Bureau of Mines, introduced the same treatment for lignite at Denver, Colorado, for conserving and collecting the by-products. The plant of 500 tons a day is of the Belgian coke oven type, with all the best improvements possible, each oven, unit or retort taking 10 tons of lignite, and the operation being completed in 2 to 2½ hours.

The lignites of Colorado are not of such a highly bituminous nature as those of Germany. The yield of oil is only 13 gallons of oil and tar per ton, and 10,000 cu. ft. of gas, owing to the far too high temperature at which the plant is operated. At the same time, the results are very satisfactory. The coke obtained is transformed into briquettes and ovoids, the latter known as carbonets, which are highly appreciated by the public for domestic purposes.

The composition of these briquettes and ovoids is as follows—

Moisture	.	.	.	.	.	%
Volatile matter	.	.	.	.	.	1.34
Fixed carbon	.	.	.	.	.	7.60
Ashes	.	.	.	.	.	84.04
						7.02
						<hr/> 100.00

Calorific power = 14,061 B.T.U.

A similar plant has now been erected in Canada, and the results are very satisfactory.

It is certain that with the recent progress and the numerous developments in the appliances to be used, and chiefly by the comprehensive employment of superheated steam, as a heat-giving agent, the treatment of ordinary bituminous coal, lignites, shales and generally any carbonaceous matter, will undoubtedly yield valuable quantities of oil, while the residue or coke will provide, by briquetting, a most valuable domestic and industrial fuel.

CHAPTER VIII

MODERN LOW TEMPERATURE PLANT

THE systems of distillation described in the following pages have been selected as representative of those now available. These instances embody the main principles on which every efficient retort is based. At the same time, they include modifications in certain directions which differentiate these from others.

The retorts not referred to below are mostly designed on similar lines to those given, though they may vary in some minor particulars and devices.

The details of the plants dealt with are drawn either from patent specifications or are based on statements supplied by the concerns exploiting the different systems.

It should also be noted that the processes referred to are equally capable of treating coal, shale, lignite, peat, sawdust and any other distillable material. Certain modifications of method and temperature would necessarily have to be made, according to the material dealt with.

The Caracristi System.

Interest in this system has been aroused by the fact that an experimental plant has been erected and operated at the Ford Motor Works in America.

This system consists of a travelling cast iron plate conveyor, which is heated by sliding over a bath of molten lead. The lead is kept at a temperature of 1,200° F. (649° C.). The coal is pulverized before treatment and is supplied continuously to the conveyor. The depth of coal on the latter is half an inch and is carbonized by the heat from the molten lead. The solid low temperature fuel is delivered at the reverse end of the carbonizing chamber. The inventor claims that it is possible to carbonize coal by this method in five minutes, on

account of the greatly increased heat conductivity due to the use of molten lead in contact with the iron plates.

It is interesting to note that a system with travelling carbonizing conveyor was introduced by Samuel Clegg, who was associated with Murdoch, both well-known pioneers of the gas industry at the beginning of the eighteenth century. The plates in this instance were, however, heated by direct firing.

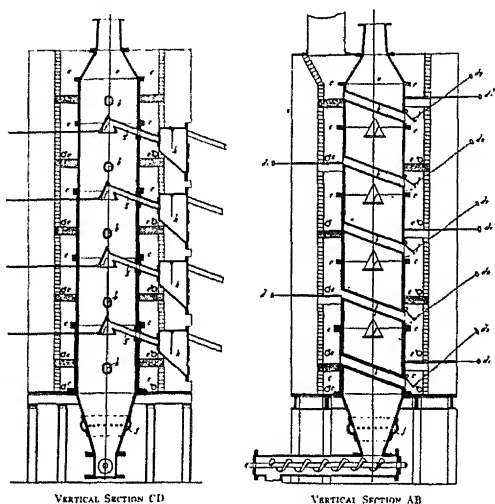


FIG. 2.—THE CROZIER RETORT

A large increase in output was claimed by adopting this method and a richer gas, but the system did not find favour among gas engineers.

The Crozier Retort.

This retort is of the continuous vertical type, with mechanical loading and off-loading. It is very similar to the Universal retort, subsequently described.

The retort is constructed in cast iron sections bolted together, making a column about 20 ft. high and heated externally by a series of flues, which form several distinct zones of heat. Each zone is regulated by dampers, the flues being constructed within the fire-brick walls surrounding the cast iron column. In addition to these flues are tubes which cross the retort diagonally and form part of the system of flues for each

particular zone. These tubes are for the purpose of supplying heat inside the retort in addition to that provided externally. Additional heat is also supplied by the introduction of steam at low pressure, obtained from an ordinary steam boiler. The steam enters the retort at various levels.

The object of these arrangements is to create a succession of zones of graduated temperatures, from the level of loading down to the off-loading chamber. Combined with this procedure is the extraction of vapours and gas produced at each of the zones referred to, by a series of outlets, the different products being conducted to a separate condenser. By this means it is claimed that a certain amount of fractionation of the oils is obtained.

With Burma shales, treated at the experimental plant at Wembley, the reaction began at from 100° to 150° C. when the first fractions began to come off. The bulk of the oil appeared to be produced at about 225° C., finishing about 400° C.

The Day Retorting Plant.

The essential features of this retort are, first, three slanting tubes, 15 in. diameter, 10 ft. long, containing screw conveyors, which transport the shale crushed to 1 in. and smaller, from the bin in the upper part of the drawing to the brick furnace; and, second, a furnace containing two sets of six horizontal steel retorts, 10 in. in diameter and 12 ft. long, one above the other, and connected at alternate ends. Small screw conveyors in the retort tubes convey the shale during its distillation from the intake at the top to the discharge valve at the bottom, where the spent shale drops on to a travelling grate. The hot-spent shale takes fire and burns on passing under the retort tubes, furnishing so much heat as to necessitate jacketing the lower tubes. The jacket superheats steam, part of which is turned into the distilling shale, and part heats the slanting feeding tubes. The vapours from the distillation go out counter-current to the on-going shale and preheat it, and are cooled by them. This heat exchange greatly adds to the capacity of the plant. The vapours are condensed and separated from the permanent gases in the usual apparatus (Fig. 3).

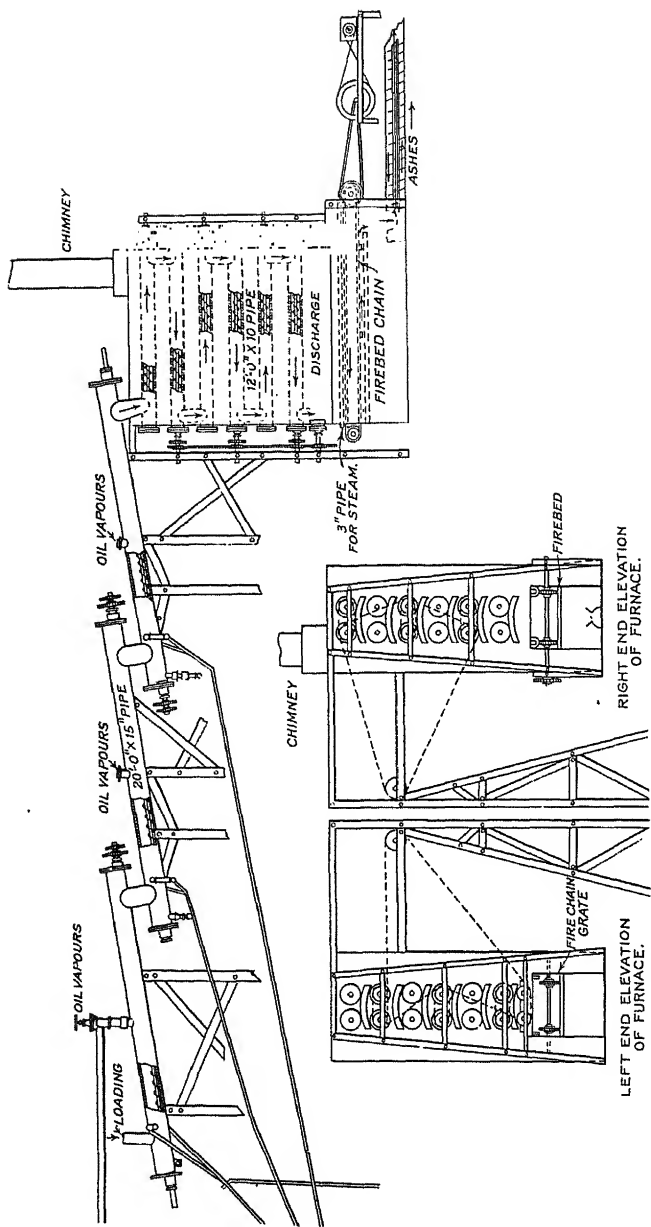


FIG. 3.—THE DAY RETORT

The Day-Heller Process.

This process consists in subjecting a mass of fresh untreated shale in a closed chamber located outside a furnace and removed from the action of the heating medium thereof to the action of hot aeriform material constituting the sole heating medium for the chamber and composed solely of

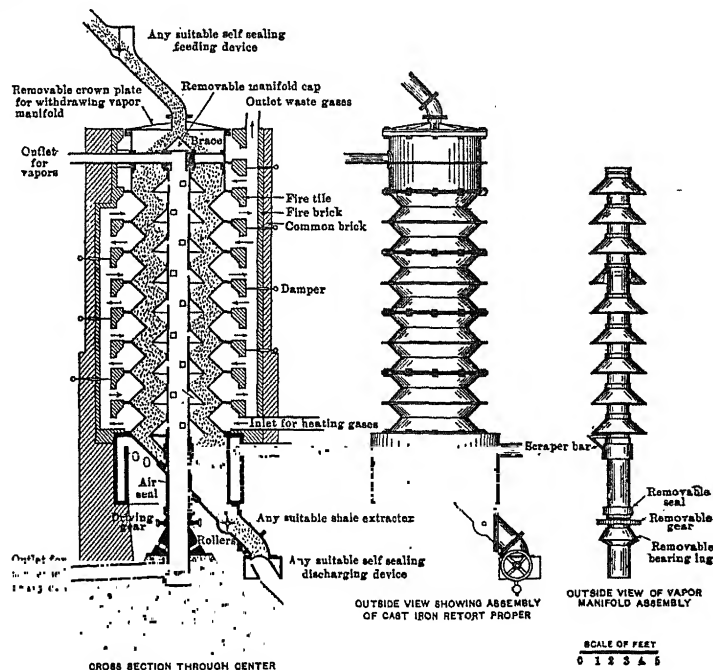


FIG. 3a.—THE DAY-HELLER RETORT

vapours and gases driven off from similar shale to distil off volatile material from the fresh shale in the closed chamber, and subjecting similar shale material to the action of heat applied to the exterior of a retort within a furnace to drive off hydrocarbon vapours and gases in aeriform condition. The aeriform material is conducted into the chamber through an opening in the lower part of the chamber and is released into the mass of shale therein, and the aeriform material is led from the upper part of the chamber, the chamber and the shale within it being altogether removed from the heating

action of the furnace gases of combustion and the sole source of heat for the chamber being from within and provided by the gases from retort (Fig. 3a).

The "Freeman" Multiple Retort.

The design of the "Freeman" multiple retort is based essentially on the fact that there is a number of definite and critical temperatures in the carbonization of coal, and the retort is divided accordingly into a number of stages or zones, each of which is kept at a definite temperature by means of special accurate automatic control mechanism. The coal passes in succession through the different stages, and remains long enough in each for the particular and definite reactions to take place, and for all the volatile products to be separated before passing in order to the next zone.

Thus, the first stage is the removal of occluded gases and water, which, according to Mr. Freeman, commences at 212° F. (100° C.), and may go on until as high as 500° F. (260° C.). The next stage begins with most coals at about 450° F. (232° C.), continuing as high as about 650° F. (343° C.), and consists in the metamorphosis of the greater part of the coal substance into a partially soluble form. During this stage no oil, and very little gas comes off, which in fact cannot happen until the transformation is complete. There is no apparent change in the constitution of the coal, but Mr. Freeman states that the process can be followed by taking samples and determining the amounts of oil by extraction in a "Soxhlet" apparatus.

The third stage is about 250° F. higher than the second stage, and the distillation of the low temperature oil commences and finishes during this period, whilst also most of the gas is given off. The temperature is not as a rule, however, allowed to exceed a maximum of about 800° F. (426° C.), and Mr. Freeman proposes to call this the critical temperature which differentiates low from high temperature carbonization. He is of the opinion that immediately above this temperature the carbonization assumes a different character, tar, pitches, naphthalenes, anthracenes, phenols, and similar substances being formed, together with an abundant evolution of free hydrogen, which are characteristic of high temperature carbonization.

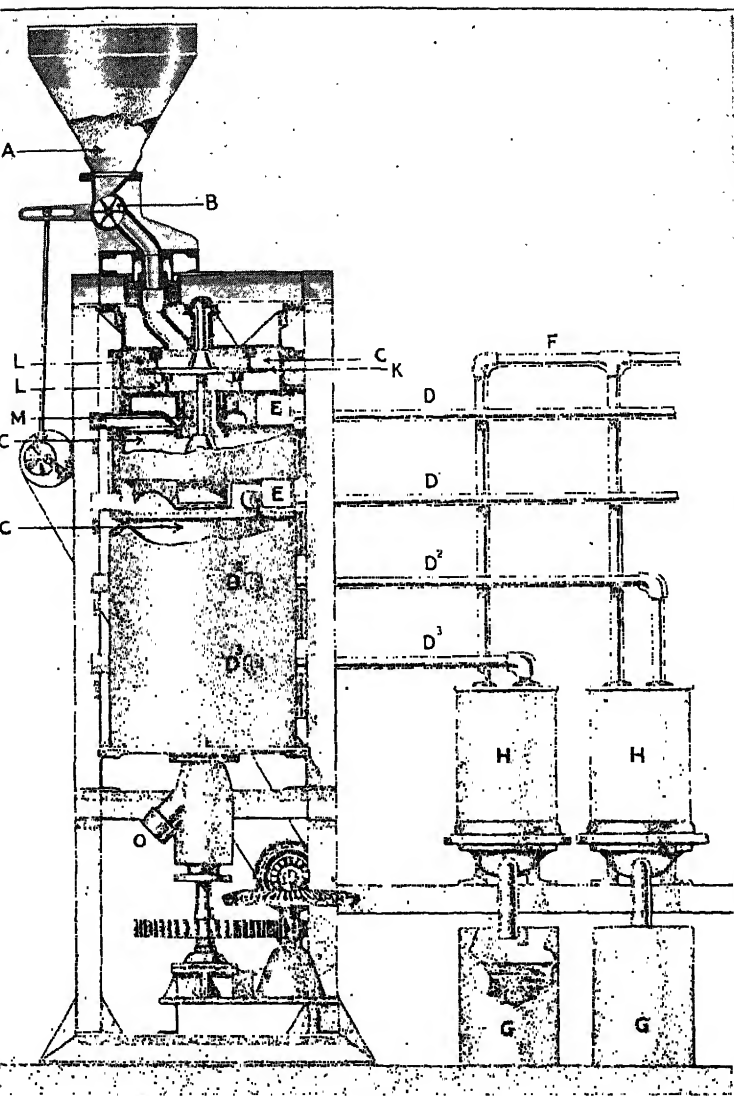


FIG. 4.—THE FREEMAN MULTIPLE RETORT

As already stated, the "Freeman" multiple retort is designed so as to submit the coal in succession to these various critical temperatures, and is constructed in six stages, the last of which is a cooling zone to enable the residual low temperature fuel to be discharged into the air without difficulty.

The retort and general plant at Willesden is illustrated in detail in the section drawing Fig. 4. The complete installation includes coal pulverizing, the conveying plant, one retort with a capacity of 10 tons of coal per day of 24 hours, an oil refining plant capable of handling 500 gallons of oil a day, a total gasification plant of $2\frac{1}{2}$ –5 tons solid fuel a day, a desulphurizing plant, and a briquetting and powdered fuel plant. The "Freeman" retort is also particularly applicable to the distillation of shale, torbanite, and similar material, and in fact was originally designed for this purpose, and subsequently adapted for the carbonization of coal and lignite at any required temperature, the installation at Willesden being designed to handle any of these fuels.

The retort is of the vertical continuous type, having a height of about 37 ft. and a diameter of 5 ft. The coal, or other fuel, roughly pulverized so as to pass through a 10's mesh sieve is conveyed automatically into the hopper (A), Fig. 1, and is fed continuously through the feeding valve (B), actuated by means of an eccentric driven from the main drive, into the first chamber or zone, each of these chambers being marked C. These chambers are heated by producer gas which enters through the pipes shown, and by means of the "Freeman" automatic regulating mechanism—which will be described shortly—each chamber is maintained at a constant temperature.

The pulverized fuel is stirred continually by means of slow moving ploughs or scrapers (LL) attached to the horizontal revolving plate (K), driven by a central vertical shaft. The fuel is in each of the chambers approximately 17 minutes, and is maintained at 350° F. for this time in the first chamber, whilst being kept in slow motion so as to expose every particle of the coal to the action of the heat. The occluded gases and practically all the moisture is driven off in this stage, the volatile products escaping through the pipe (D). When the

coal has completed its travel round the chamber in 17 minutes, it falls through the chute (*M*) into the second chamber below. Here the temperature is maintained at 450–500° F., being, as before, stirred slowly and kept in this stage for 17 minutes. Here the remainder of the moisture is driven off through pipe (*D*₂), and the transformation of the coal substance takes place. In the third stage the temperature is 600° F., and a considerable amount of light oil is given off, together with gas, the volatile products as before passing through the exit pipe (*D*). Each of these exit pipes (*D*) is connected to a coal condenser (*H*), cooled with water. The condensed liquid products collect in the receivers (*C*), and the gas passes on to the gas main (*F*) connected to a gasometer.

In the fourth stage the temperature is 650° F., and a considerable portion of oil and gas is evolved, whilst in the fifth stage the temperature is 750–800° F., the last of the oils being driven off. The last stage is simply a cooling chamber, with a current of cold air passing round the outside. The low temperature fuel, being, of course, in the pulverized condition, is then discharged through the discharge pipe (*O*) into a truck, or any convenient receptacle. The temperature of the residual fuel passing through *O* varies from 106°–400° F., depending on the quality of coal and the speed of working, and the design of the cooling chamber prevents all danger of the fuel igniting when it comes into contact with the air. The method of driving the retort will be clear from Fig. 4, consisting of a vertical driving shaft, to which each of the revolving plates are attached, with horizontal gear wheels driven by motor. The power required is very small, being for this size of retort only about 5 h.p. An essential part of the "Freeman" retort is the "Freeman" precision temperature regulator.

This embodies an air lead or tube to the source of heat, a separate regulator being connected independently to each chamber. This air lead terminates in an air bulb, which is placed directly in the heated chamber. The slightest change in the temperature causes a corresponding expansion or contraction of the air inside the bulb. This bulb is in connection with a short column of mercury contained in a glass tube at a slight angle to the horizontal, and the change in volume in the bulb

causes the mercury column to move accordingly, the mercury making a contact with a point, the position of which can be adjusted by the fine screw thread. Also in direct communication with the air lead from the air bulb is a column of oil contained in a vessel, in which a glass tube dips below the surface forming an oil seal, which also serves as a convenient indication to the attendant as to the change of temperature in the chambers. The horizontal mercury column is mounted on a trunnion, so that it can be rotated as required and brought, if necessary, almost completely horizontal, the smaller the angle to the horizontal the more sensitive being the instrument. A valve is fitted in the producer gas supply pipe to the chamber, operated either by a compressed air piston, or a solenoid magnet, operated by a nitrogen tube switch, actuated by an electro-magnet. This magnet is excited when the mercury column makes contact with the point referred to.

The Fusion Retort.

The heat required for the treatment of the material is obtained from the combustion of gas from a Producer gas plant, or from a hand-fired or mechanically operated fireplace. This chamber assures the complete combustion and for mixing of the gases. These heating gases then enter the heating chamber through a number of parts placed in the wall between these chambers. The parts are so placed and can be so regulated that the temperature at any part of the retort may be controlled. The heating gases are admitted into the heating chamber at the discharge end of the retort, pass round the rotating tube, and leave the chamber at the feed end through a flue coupled to the chimney (Fig. 5).

The retort tube is set horizontally in the heating chamber, and is driven by means of spur gearing from any suitable source of power. At the feed end of the retort is mounted the automatic feeder which is driven direct from the retort. This feeder is so arranged that whilst it is working the quantity of material being fed to the retort may be varied. In the retort tube are placed breakers (Fig. 6), which may be in one or more lengths, usually not less than five, and they may have three, or

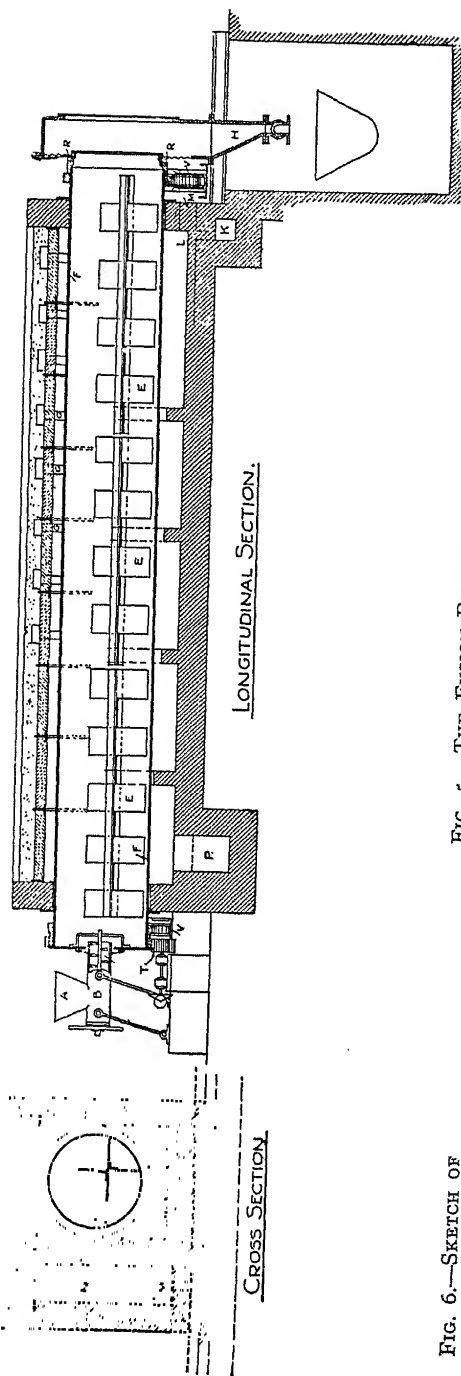


FIG. 6.—SKETCH OF
BREAKERS

FIG. 5.—THE FUSION RETORT
(Sectional View)

more, points or blades. These breakers are not driven by any external or internal means and are not fixed in any way, but are placed loosely in the retort, so that as the retort tube rotates the breakers keep falling over and over, and in so doing give a hammer or chipping action. They thus prevent the birth or growth of scale on the walls of the retort and break down lumps of material which would otherwise form. It will be appreciated that owing to the fact that all materials rich in oil pass through a caking or plastic state, any form of scraper, such as a worm driven by a shaft, or paddles driven by a shaft or the like, would be useless, as they would not prevent the birth or growth of scale on the retort or on the worm or paddle themselves. Owing to the fact that the edges of the breakers, or the edges of the blades of the breakers, fall on to the bed of material being treated, the retort is practically silent in action and the wear and tear is negligible.

At the discharge end of the retort tube is placed a stationary chamber, usually of cast iron, which acts as a receiver for the residue or the material after treatment. The connection to the condensers is also coupled to this end chamber through which pass off the gas and oil vapours.

The residue, or material after treatment, passes out of the retort through the automatic discharge valve. This automatic discharge valve is so arranged that the moving metal parts do not come into direct contact with the stationary metal parts, so reducing wear and tear to a minimum. The valve is so arranged that it will discharge exactly the quantity of material it receives. The oil condensers may be either atmospheric or water-cooled, or a combination of both.

The bituminous material under treatment should be prevented from attaching itself to the sides of the retort, and also from caking together to form lumps.

In the "Fusion" retort there are breakers which keep the tube clean and clear from scale and break up any lumps which tend to form.

In most cases oil commences to come off at slightly above 50° C. and continues to come off up to temperatures varying between 400° C. and 600° C. according to the material and method of treatment. To prevent the destruction of the

ghter oils it is essential that the temperatures should be gradually and uniformly increased.

The material enters the tube at atmospheric temperature and is gradually heated as it travels forward and the forward movement into and through the higher temperatures is regular and uniform.

In order to secure a maximum recovery of the oils, and to prevent their partial destruction, it is essential that the material while subjected to a steadily increasing temperature should also be kept under constant agitation. Scale or crust on the walls of the retort will cause local overheating.

A gradually increasing temperature is ensured by the forward passage of the material under rotation and agitation, and scaling and caking are prevented by the action of the breakers. The whole operation is mechanical, so that poking is unnecessary.

If the heat has to pass through one part of the material in order to reach another part, the outside temperatures will be higher than those within, with the result that either the outside temperatures are too high and destruction of oil takes place, or the inside temperatures are too low and some of the oil is not extracted.

The thickness of the material being treated in any part of the retort is not more than a few inches, and the material is so constantly changing its position that that which is farthest away from the retort wall at one moment is in contact with the wall at the next moment.

The whole of the material mined ought to be utilized, and it ought not to be necessary to reject the "fines."

The whole of the material as mined is passed into the feeding chamber, and the breaker in the retort reduces the coarser parts to a fine condition. It is in fact wasteful to subject any but fine material to the action of heat since the total of free surface from which the oil can distil is greater in the case of a number of particles than in that of a lump of equivalent weight. In other words the rate of distillation varies with the area of surface exposed. Much lower maximum temperatures for a given recovery of oil can be employed when the material is crushed fine before retorting.

The adaptation of methods and conditions of retorting to each particular material is a point the importance of which

has frequently been lost sight of, with the result that many valuable retortable materials have been condemned. Adaptability is therefore to be regarded as one of the essential features of any modern retort.

The " Fusion " retort can readily be adjusted to the requirements of various retortable materials by altering the heat of the furnace, the speed of rotation, the speed of the automatic air-tight feed valve, and the weight and shape of the breakers.

To summarize briefly the outstanding points of the system. It is capable of utilizing the whole of the material mined ; of extracting the maximum quantity of oil at minimum temperatures ; and it ensures the preservation of the lighter oils. On the economic side, the system effects a reduction of refining costs and of loss on refining, and the preservation of the more valuable finished products, with the minimum of supervision and labour. Continuous and automatic feed of raw material and discharge of spent material are also features of importance, while adjustment of the retort to the nature of various retortable materials is also readily effected. The erection of the plant is simple, repairs are easily carried out and the first cost of construction is low, a large part of the ironwork and the whole of the brickwork can be obtained from some local source, and as additional is not required the usual boiler and superheater are eliminated.

A few of the interesting figures obtained are given below. In all cases the figures are based on the " wet " ton, that is on the raw material in the state in which it was delivered to our testing station. If the figures of oil yield were based on the " dry " ton (which is the usual, but misleading, method adopted for expressing the yield obtained) they would be considerably higher than stated.

The specific gravity given is that of all the oils produced mixed together at the end of the test.

The table (shown on page 62) gives the results of tests carried out on various descriptions of materials.

The Gordon Retort.

In the Gordon retort, illustrated in Fig. 7, the material is broken up into pieces that would readily sieve through one

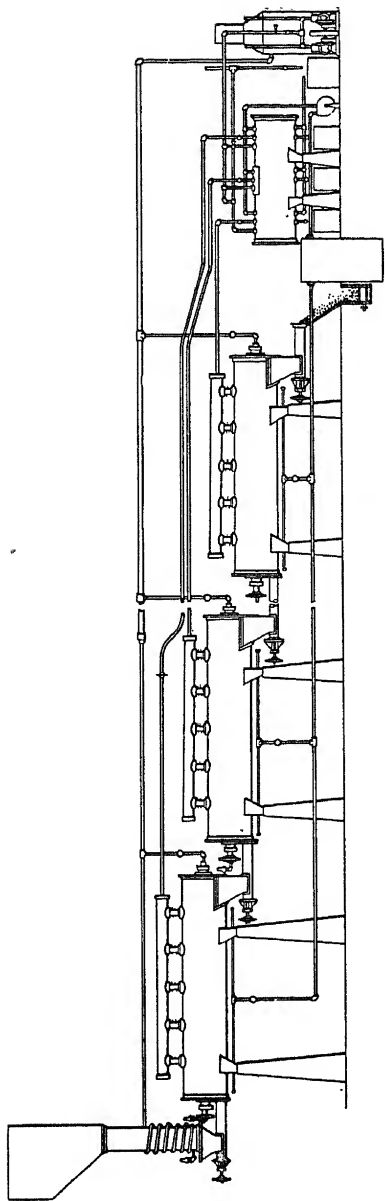


FIG. 7.—THE GORDON MULTIPLE UNIT RETORT

quarter mesh (wood only need be hogged), and is dumped into the hopper. It then passes through a preheating chamber which dries the material. The dried material then passes from this preheating chamber to a hopper from which it is conveyed by an auger-like conveyor to the first retort. This retort is heated to a fixed low temperature which will volatilize all of the light family of products. In it revolves a spiral conveyor between the blades of which are attached scoops which agitate the material so that every particle receives equal heat and thus expedites through volatilization. This conveyor revolves at a fixed speed and allows the material a certain length of time to pass through this retort. At the end is another hopper through which the shale drops to a spiral conveyor which

RESULTS WITH THE FUSION RETORT (see pp. 55-59)

Material treated	Moisture in Raw Material %	Gall. of oil (water free) per wet ton	Specific Gravity of oil	Cu. ft. of gas per wet ton
South African Torbanite . . .	0.5	96	0.9175	1,770
English Oil Shale	12.58	31.5	1.016	1,850
Sawdust ¹	13.79	17	1.1274	2,200
Indian Coal	10.92	23.8	0.9592	1,125
Peat	28.65	9	1.051	3,000
English Coal Slack	6.72	16.4	1.122	1,025
English Cannel Coal	1.54	60	0.912	870
Esthonian Shale	4.18	65	0.9571	1,340
Brown Coal	27.0	22.5	1.102	1,300
South African "Duff" Coal . .	3.65	14.6	1.050	1,570
Nova Scotia Shale	1.75	28.2	0.9871	1,120
English "Duff" Coal	2.3	21.5	1.120	1,960

¹ In addition to the oil recovered there were 102 galls. of acid liquor of 1.26% acidity.

The above figures of Oil Yields do not include the Light Spirit recovered from the permanent gases by "stripping" or "gas washing."

passes it along to the second retort. These intermediate conveyors are of a relatively small diameter and therefore work at an increased speed. The action of the shale coming down from the retort fills them to a capacity and thus makes an air seal which prevents the heat and gas of the retorts from passing back into the previous or lower-heated retort. The material in this second retort is then subjected to a higher heat which drives off the medium family of products. As in all the retorts, this vapour is conducted through vertical tubes at the top of a condenser. The vertical tubes have adjustable baffle plates which prevent the solid material, such as dust, from passing through the tubes and into the condenser. The shale then passes from this retort through a similar hopper and a conveyor to the third retort where like treatment under still higher heat drives off the heavy vapours. The residue then passes out through a hopper and the spiral conveyor to another conveyor and there this residue is passed to bins or storage.

As indicated before, the vapour driven off rides through the vertical tubes to the vaporizing chamber through the conveying tubes to a suitable condenser. There the vapour is liquefied and is drained off. Part of the vapour driven off will not condense and this gas is allowed to pass from the top of the condenser through pipes to a vacuum pump. The action of this vacuum pump not only draws the gas from the chamber but also tends to create a region of low pressure in all of the conveying tubes from the retorts and thus expedites the conveying away of these vapours so that scorching and combustion will be prevented. The gas from the vacuum pump is delivered to a gas storage tank from which it passes through suitable pipes which connect with the exterior burners and heat the separate retorts. These gas pipes are all equipped with valves which allow the temperature in the retorts to be regulated.

The Griffiths Retort.

The Griffiths retort is of the horizontal rotary type of rather limited length, not exceeding 20 ft., and of small diameter, about 8 in. It is constructed of very thin material, so that the heat may be rapidly distributed. The retort is

closed at both ends, and the charge is fed and withdrawn by means of a small feeding screw. The temperature is regulated in such a way so that it gradually increases from the feeding point to the exit where a temperature of about 400° C. is reached. From beginning to end, this is rapid, the passage of the material to the maximum-heated zone occupying only from two to three minutes. The bottom of the retort is fitted with a system of metal brushes, arranged in the form of a spiral, round a fixed shaft, which revolves in the cylinder, so that the material is in constant disturbance throughout its passage along the retort. These metallic brushes also clean the shell of the retort by friction, but, being made of very conductive metal, they absorb a good deal of the temperature and impart it to the retorting material at the same time as the stirring process is proceeding. This method assures the material being thoroughly heated, and as the whole process is carried out in so short a time, during which the charge is in contact with the maximum temperature, all volatile matter of the oil constituents is entirely extracted and removed. The nature of this oil is exceedingly light, and contains a large proportion of motor spirit. A certain number of these retorts can be fitted together at each end and worked simultaneously. It is understood that the moisture and light gas contained in the material used acts in such a way as to react with the friction involved with the original maximum temperature referred to above. The irreducible gases obtained, after stripping the gas as well as any inert gas or superheated steam, can be injected into the retort to assist the reaction.

The essential claims of this invention are the small diameter of the retort, the rapid passage of the material through the critical maximum temperature, and the light specific gravity of the oil obtained, while the gas evolved appears to be exceedingly small in quantity. The working of the retort is entirely automatic (Fig. 8).

The Hartman Process.

The inventor of the Hartman process claims that his system is constructed along practical and scientific lines, after considerable expenditure, experiments and a thorough testing of

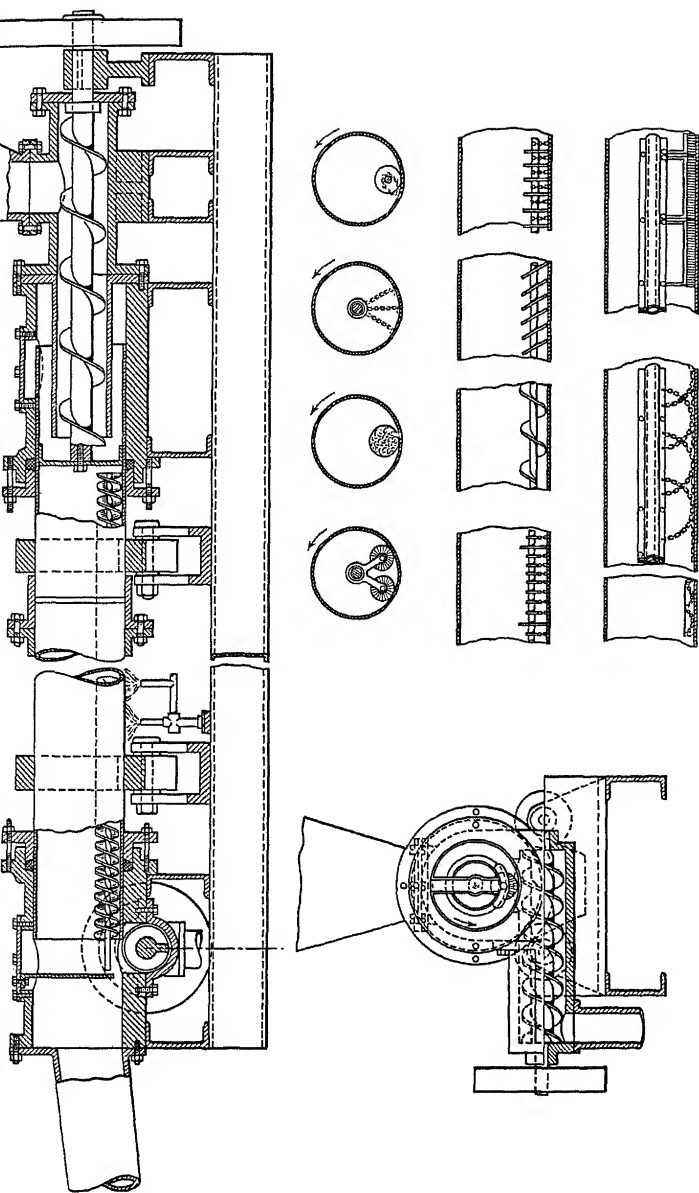


FIG. 8.—GRIFFITHS RETORT

Above is general section of plant. On left, section of unloading appliance. On right, various systems of internal rotary brush.

different shales. The inventor states that there is no oil in shale as such, but it contains a fatty substance, which by the use of heat, is converted into petroleum. Now the first scientific point of the Hartman process is that after these fats are converted into petroleum, the vapours are immediately removed and taken off through the central tower, with a flow of steam rising from the two lower decks.

By this operation the immediate taking of the gases and vapours to the condenser, the process is insured against re-distillation of the oil.

The Hartman process is absolutely continuous in its operations and is controlled by pyrometers, and a thermostat system which in turn controls the burners, so that the retort is held within 20° of the required temperatures.

The coal or shale is fed in to the crushers, from the crushers it passes down a chute to the upper trap, which trap has automatic feed control, passing the shale automatically into the retort and does not allow the escape of gases or vapours nor does it allow air to get into the retort (Fig. 9).

After the shale passes through this trap, it is dropped upon a deck which is circular. On this first deck, which we will call number 1, the shale is moved around the inside circumference of the retort, which is 7 ft. in diameter, causing the shale to travel at its extreme point 21 ft. This shale is moved by a circular agitator which acts as a conveyor, and which is raised 1 in. to $1\frac{1}{2}$ in. above the floor (the floor meaning the table or deck), which holds the shale in its proper place. The conveyor moves the shale around the deck in the retort inside to an opening in the floor just 12° back where it receives the shale. On passing around the first deck the shale is pre-heated and then dropped to the second floor. The operation is repeated on the second floor.

In making the circuit of this deck the shale begins to release the water it contains in the form of steam. The mineral then drops through the floor of the second deck to the third.

Practically all the water the shale contains is thrown off on the third deck, in the form of steam, and it then drops to the fourth deck.

In passing around the fourth deck, the shale begins to be

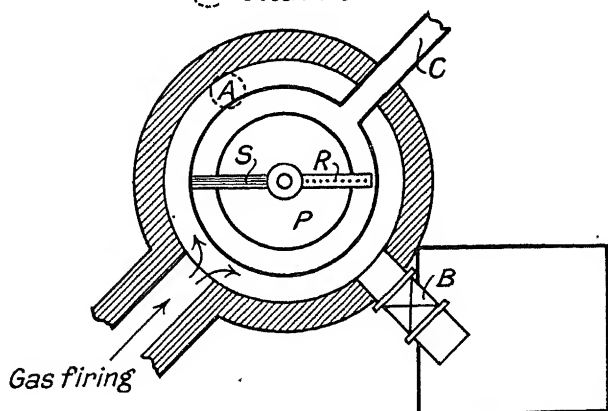
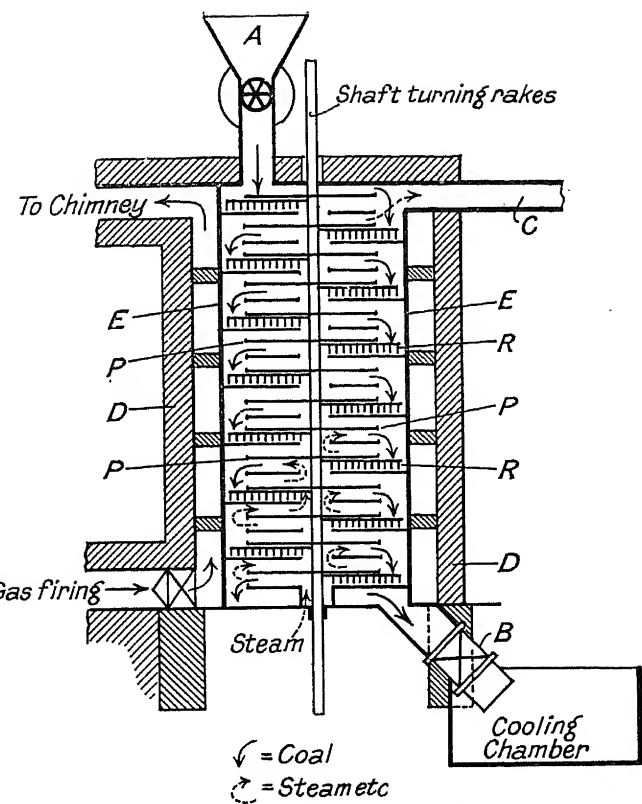


FIG. 9.—THE HARTMAN RETORT

Loading. (B) Off-loading. (C) Vapour to Condenser. (D) Masonry. (E) Steel Shell.
 (P, R.) Baffle Plate and Rack. (S) Slit to Pass Coal.

destructively distilled and vapours start passing off, rising in the central tower with the steam released from the upper floors, the shale then drops to the fifth floor.

On the fifth floor the temperature is 200° hotter than on the first floor, or about 680° F.

A heavier destructive distillation takes place on this floor, and the lighter oils are removed in the operation.

After passing to the sixth floor the heat is increased, the heavier vapours start coming off. After making the revolution of the sixth floor the shale is passed to the seventh floor.

The seventh floor reaches a temperature of 900° F.

It is then passed to the eighth floor and after revolving the circumference of this floor, practically all the heavy fats in the shale are distilled.

Upon passing to the ninth floor a light spray of superheated steam is directed on to the shale. This superheated steam increases the quantity of oil recovered, for the following reason. The hydrocarbon oils are composed of hydrogen gas and carbon vapours, roughly in the proportion of 15 hydrogen and 85 carbon. The shale itself contains more carbon than hydrogen, and when these proportions are considered and when the hydrogen which is in the shale has combined with its proper proportion of carbon, there is still some carbon left but not enough gas to take it up. When the superheated steam is turned into the retort it is disassociated into hydrogen gas and oxygen, and this hydrogen gas which comes from the steam combines with the carbon left uncombined in the shale, to make additional oil, while the oxygen creates a water gas which increases the fuel derived from the shale to a very great extent.

The shale dropping to the tenth floor is subjected to a temperature of about $1,200^{\circ}$. On this tenth floor it receives a very heavy spray of superheated steam, which destroys or explodes the hydrocarbons left in the shales up to this point, and causes the production of a large volume of gas.

After revolving around the tenth floor the shale meets with a large opening in the floor, just behind where it passed from the ninth floor, and it drops into a chute and runs into the discharge trap which automatically discharges the spent shale from the retort.

The reason for the oil not being burnt or re-destructed, and the reason as per first question of why this retort manufactures more oil from the same shales than any other retort is, says the inventor, that the shale is gradually heated, from the first to the tenth floors, ranging from 500° to $1,200^{\circ}$ F. of heat.

The retort is so constructed that in the centre of the circular chambers is a 3 ft. opening, where the vapours immediately they leave the shale at different temperatures, move into the central tower, and by the high speed of the superheated steam, especially the large volume rising from the lower floors, the gases and steam are immediately carried to the dome at the top of the retort and passed through the condensers.

After passing through the condensers at high speed they are carried into a large scrubber, which is a large high tank filled with mineral wools. The oil which is conveyed drops to the bottom in this tank and is drawn off on to its respective receptacles. The gases pass through the mineral wool to the extent of 10 or 12 ft. The vapours are mostly condensed and scrubbed, the oil falling back to the bottom, and the gases rising to the top are drawn with pressure back to the burners, thus manufacturing the fuel for the heating of the retort. In further explanation of why the oil is not re-distilled in the Hartman retort (process No. 7) is that on all floors that the shale passes over, the temperature is from 50° to 100° hotter and, upon the destructive distillation beginning, the vapours leave the shale immediately and move to the centre, mixing with the steam from the lower portion, which steam is 100° to 300° cooler than the respective places of destructive distillation.

The intake and exhaust traps are both operated from the same gear box and the same proportionate speed. The speed of the agitators is one revolution every four minutes. The openings are set so that they drop approximately one cubic foot of shale between the partitions of the circular agitators, as they pass under the trap, which agitator has 24 compartments.

Therefore, the upper trap dumps 24 times to each revolution

of the main agitator, and is so arranged that the dropping from floor to floor is automatic. It is therefore impossible for this automatic feeding device to overload the retort or choke it; the lower trap having a discharge capacity of one-third greater than the upper trap, insuring at all times the removal of the spent shale.

The retort is so constructed that all of the agitating conveyors are carried $1\frac{1}{2}$ in. above the decks or floors, allowing the shale to creep under them and cause the tolling of the shale, instead of a drag push. With this method 50 per cent of friction is eliminated.

As to the gearing, the gear drives one set and is gauged at 1,500 to 1 and can be driven by a 25 h.p. engine or motor.

These agitating conveyors are all connected by a shaft, and the entire weight is carried on heavy truss bearings 4 ft. below the fire box, and run on oil. The drive of the plant is on the other end of this shaft above the dome, on top of the retort.

The fundamental principle of this number seven retort is that there is not a metal friction part or bearing inside to get out of order or cause trouble.

CONDENSER. This is the most important feature in obtaining a high-grade shale oil. The Hartman condenser has been worked under actual tests and experiments to prove its efficiency and to fulfil the requirements for producing a high-grade oil. The vapours are precipitated by centrifugal force and are then pushed through a specially designed condenser to the scrubber.

In a large cooling chamber in which is placed 4 fans (4 ft. blades) which take the vapour from the rear and drives them with high pressure against a cold wall and on through the condenser. The centrifugal force is so arranged that by the use of air valves any amount of suction can be obtained. This point is very important, first, because if there is any vacuum on the retort, it pulls the heat and dust and prevents the proper conversion from shale fats to petroleum, and at the same time if there is pressure on the retort, it induces the cracking and distillation of the oil.

Therefore, it must be taken off at exactly the right pressure,

the oil as it leaves the retort being practically dead from the tremendous heat necessary for distillation. The Hartman condenser puts the life back into this oil with centrifugal force by taking air through the valves just behind the fan and mixing it with the oil vapours. This restores the oil to a high-grade petroleum, and therefore makes the refinery work very simple and easy. The point and feature of heating is that we are carrying the shale around in the small space of 10 ft. by 19 ft. and has to travel a distance of 180 ft., and the small surface of this retort which requires heating reduces the area to a very small proportion to the amount of shale it handles. There are approximately 6 tons of shale in the retort at one time which is continuously passing through every thirty minutes making, approximately, 12 tons per hour or 288 tons per day of 24 hours.

The Hartman retort generates from a third to a half more gas than is required for its fuel and after once in operation no other fuel is required other than its own production.

The cost of labour is very light as the entire retort can be handled by a thermostat system, and as the retort is automatic in its entirety a watchman near the retort is all that is necessary.

The automatic conveyors remove spent shales from the retorts and for carrying the shale to the crushers, and no manual labour is required after it leaves the crushers. The retort does all the work automatically and, therefore, is very economical. In a great many of our shales deposits (American) a steam shovel is all that is required and by this method a great amount of labour which would otherwise be necessary is eliminated.

This means in open cut work that on the average shale oils should be produced at a cost not to exceed 30 cents per barrel and where mining operations are necessary the oil should be produced at a cost not to exceed 70 cents per barrel with a battery of 40 to 20 units. Each retort constitutes a unit.

In conclusion, the inventor asserts that with this retort properly set up, and with proper apparatus for handling, the cost of open-cut mining and getting the shale to the crushers

ould not exceed and will not exceed, under proper management \$0.25 per ton, while crushing, retorting, and overhead expenses of the plant should not exceed \$0.45 per ton.

After careful consideration and investigation of the methods of handling shale oil, Mr. Hartman suggests that the most practical method would be to attach to your retort a high pressure cracking process to produce gasoline, the residue being used for fuel in the cracking plant, if necessary.

The amount which comes off in the ammonia liquid, or water, as commonly called, is very easy to extract. There are many by-products, but he would not recommend any corporation installing Hartman Process or any other process with anything but the plant required for ammonia sulphate and for cracking the oil into gasolene.

The Lamplough-Harper Process.

The essence of this process is to effect the carbonization of the coal or oil shale at a low temperature, which can be easily regulated to remove the elements forming oils as quickly as possible from the retort, and to complete their combination and the formation of oil and saturated hydrocarbons in a special condenser appropriated for that purpose, and to complete the condensation of the light oils and naphtha in a final cool condensation tower. (Fig. 10.)

In this process no gas is evolved—all the oil products are collected in the condensing towers; there is no need of special appliances for stripping the gas—oil pumps, scrubbers, etc. The heavier oils are collected at the base of the first tower and the light oils or naphtha collected at the bottom of the second tower.

The process is an improvement on a patent taken out as far back as 1914 for the treatment of coal and oil shales.

It treats the coal, shale, or torbanite, etc., either in a vertical retort, if the material treated does not expand or stick during the process; or in a horizontal retort with a pushing screw, if the material presents a disposition to swell or to become sticky.

The through-put is capable of adjustment and so is the temperature.

The retort consists of ten metallic cylinders, 18 in. internal diameter. The shell of each cylinder forms a steam jacket. The cylinders are provided with a metallic wormscrew, which moves the material through the whole 120 ft. of their length—in an opposite direction to the circulation of the applied heat.

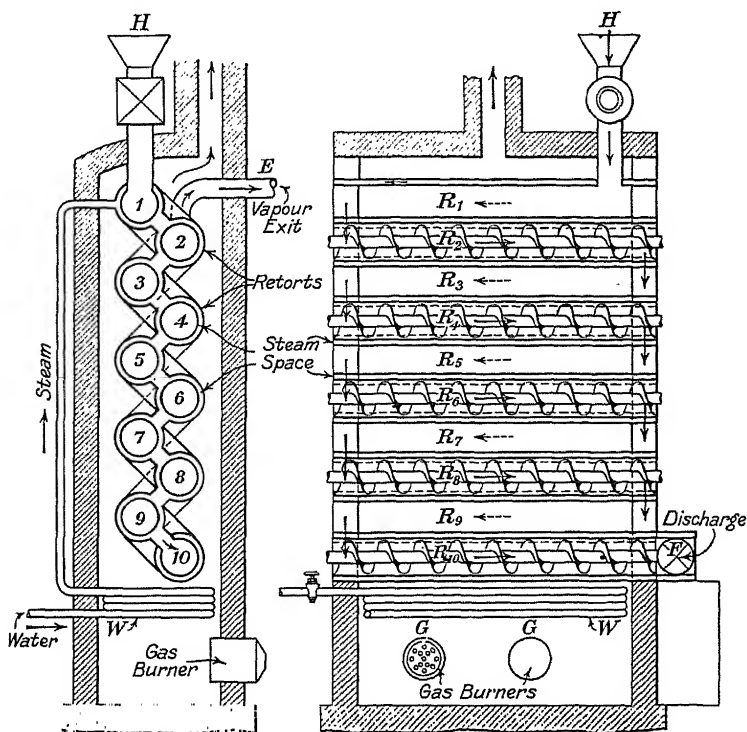


FIG. 10.—THE LAMPLOUGH RETORT

(E) Vapour Exit.
(H) Loading.

(F) Discharge.
(R) Retorts.

(G) Gas burners.
(W) Steam coil.

The cylinders are superimposed, and the material is introduced at the upper cylinder, and passes successively from one to the other till it reaches the bottom. Both the feeding and discharge are automatic, by means of an appropriate appliance, such as is generally used for such purposes and operated together automatically, so that the "feed" and "discharge" synchronize.

The retort is enclosed in a structure of fire-bricks and heated by gas obtained from a gas producer, using the residue of the retort after distillation. The necessary steam is generated in a pipe coil lodged at the base of the retort, the steam being conducted to the upper cylinder and let into the outside shell or steam jacket, passing from there into the successive cylinders, and finally reaching the bottom one, which is at the highest temperature, and getting properly superheated. It is then introduced into the retort itself, where it percolates through the masses of heated material, finally coming out of the retort at the last but one cylinder on the top, carrying away the oil vapours, hydrogen, and hydrocarbons developed.

From the foregoing, it may be seen that the working of the retort is continuous, and once regulated as to the conditions of temperature, steam and feeding is perfectly automatic, and requires little attention. The retort fully loaded carries 3 tons of material—the time allowed for experimental treatment of oil shale or torbanite is from $1\frac{1}{2}$ to 2 hours; therefore with the material remaining $1\frac{1}{2}$ to 2 hours in the retort, the rate of progress required from the wormscrew is 80 ft. per hour, or, say, 1 ft. $\frac{1}{3}$ in. per minute, giving a production of $1\frac{1}{2}$ tons to 2 tons per hour, or a through-put in normal working of from 40 tons to 50 tons a day.

The vapours with the current of steam, at a few pounds pressure, are carried out of the zone, where they originated, as soon as they are evolved, and no vapour or gas is ever submitted to a temperature superior to the one at which it has been generated, and consequently no deterioration or cracking of oil elements is possible.

The material treated passes through several preparatory zones, and is kept continually on the move. The first action which takes place is of heat absorption. The shale or torbanite, which at this period is exothermic, gradually absorbs heat, and practically is restored to life. At this point, the material has progressed in the retort, and the necessary degree of heat saturation is reached. This is the most critical part of the treatment, and has to be reached very gradually, otherwise the shale or torbanite becomes violently exothermic, and

the excess of heat developed may destroy the unborn fractions.

Such violent action is, however, prevented in the process, as the shale or torbanite, on reaching the exothermic state, has travelled into the zone of reduced temperature, ebullition of excess of heat is at once absorbed by the surrounding medium of steam, and the danger of any possible reaction is entirely averted. The shale or torbanite then distils properly, and gives birth to the first fractions, the material passing gradually into successive zones of higher temperature, and successively gives off fractions in order of their specific gravity, until the hottest zone or lowest cylinder is reached, when the spent material, having given up its latest fraction, is passed through the automatic trap into the cooling chamber outside.

The steam circulating in the steam jacket, round the cylinder, travels in the same direction as the material retorted; it prevents any direct firing of the flames on the metallic shell of the retort and regulates evenly the temperature; and when introduced into the retort, the steam finds its way through the material and coming into reaction takes place, hydrogen and hydrocarbon gases are evolved, and in their nascent state join up and form oil vapours and saturated hydrocarbons, which are rapidly removed with the steam out to the top of the retort and into the condensing or hydrogenating tower.

The process followed in these condensing towers is of great simplicity and efficiency; the first tower is kept hot: it has the temperature of the steam and vapour issuing from the retort. This mixture of vapour issuing from the retort, with about 5 lb. pressure, is introduced at the base of the tower, and is forced through a succession of finely perforated circular screens, which realize a perfect contact between the various elements—oil vapours, hydrocarbons, hydrogen, unsaturated hydrocarbons, completing the saturation of the latter, the heavy oils condensing and dripping along the screens absorb these various elements as they combine, and the result is the complete condensation of all the volatile products of distillation elements, oil vapours, hydrocarbons, hydrogen,

5

unsaturated hydrocarbons, completing the saturation of the latter, and achieving the work partially done in the retort.

The heavier oils condense in this tower, dropping along the diaphragms, scrubbing and absorbing gases and vapours which percolate through the perforated plates of the diaphragms.

The lighter vapours from the dome of this tower pass into the second tower, which is formed of two parts: the upper part through which pass the vapours coming from the hot tower is a circulating water-cooler, where the vapours are completely cooled; and condense and settle in the lower part, which is formed of a series of concentric compartments from the periphery to the centre. Once the vapours arrive at the centre there only remain uncondensed a trace of gases, a little sulphuretted hydrogen (if there is any sulphur in the material treated), and air from the water used. The naphtha collected in this tower contains the lightest material—with torbanite, it contained 8.6 galls. to the ton of motor spirit.

The water required for steam is about 75 galls. per ton of torbanite, yielding 150 galls. of oil per ton. The quantity required has to be regulated according to the action in the retort of the material treated, and the amount of steam required to operate and regulate the action of the shale or torbanite when it passes through the exothermic period. The heat evolved at this period is nearly regular, and increases in ratio with the amount of volatile matter contained in the material treated.

The steam used condenses completely in the two towers and separates from the oil, and can be used over and over again. A small addition is required from time to time to meet the unavoidable loss in handling the water. The coil, or tubular boiler on a small scale, lodged at the basis of the retort, is fed by a special duplex pump, with variable stroke. The volume of water supplied can be altered without stopping the pump, and thus enables one to regulate with precision the amount of steam in circulation by the amount of water sent into it.

The later treatment of the oils received is carried out on

the usual lines, but the separation of the lighter products may be advantageous in view of this subsequent treatment.

“ Low Temperature ” Process.

(Low Temperature Carbonization)

This process is effected in the Parker Vertical Retort as illustrated in the Plate (Fig. 11).

The Retort consists of 12 tubes cast *en bloc*, approximately 9 ft. in length and an average of 5 in. diameter. The Retort is shown in the front elevation and end elevation marked “ A.”

The Combustion Chamber is shown in section at the left-hand end of the front elevation between two retorts, the burners being in the cavities at the bottom of these combustion chambers. The burners are fed with gas produced from the carbonizing of the coal in the retorts through the gas main “ G ” and led to the above mentioned burners, the products of combustion passing from the combustion chamber down all four sides of the retorts and out into the central flue “ O ” in the centre of the battery.

These retorts are kept at an internal temperature of from 550 to 600° C. Coal is drawn from an overhead bunker into the travelling coal skips “ H ” and fed through the top chamber “ B ” into the tubes of the retort proper. After carbonizing for four hours, the middle door “ N ” is opened and the “ Coalite ” dropped into the cooling chamber “ I ” where it is allowed to remain for a period of four hours to cool. After emptying the retort the middle door “ N ” is closed and the retort refilled with coal. After carbonizing for a further period of four hours, the cooling chamber door “ J ” is opened and the “ Coalite ” withdrawn, the door being once more shut and the middle door “ N ” opened again and the chamber refilled with “ Coalite ” from the retort, and this cycle of operations is carried out on every pair of retorts once every four hours.

The capacity of each retort is from $5\frac{1}{2}$ to 6 cwts. of coal per charge.

The gas passes from the top chamber “ B ” through the gas off-take pipe “ C ” through a “ Cort ” valve “ D ” into the

hydraulic main "E" where a considerable proportion of tar oil and ammonia liquor is condensed. The gas is withdrawn from the hydraulic main through the rich gas main "L" and led away to the usual condenser and tar extractor by means of an exhaustor. It is subsequently treated in an ordinary ammonium sulphate plant and passed on through a gas cooler to the benzol scrubbers where the benzol is stripped from it and recovered in an ordinary benzol still. The gas then passes on to a holder and if required for the public gas supply, it is put through purifiers. If required to be used only for heating the retorts it is returned without purification from the holder to the gas main "G." Should the whole of the gas be sold for town purposes a gas producer is used or the purpose of supplying gas for heating the retorts.

The tar oil and ammonia liquor condensed in the hydraulic main passes off at the right-hand end of the hydraulic main through the small pipe shown in the front elevation and is led off to a tank which also acts as the reservoir for the oils collected in the gas condenser and the tar extractor. The tar oil is allowed to settle in this reservoir tank and separates out from the ammonia liquor by gravitation, the ammonia liquor being pumped from the top of the tank and the tar oil from the bottom. The tar oil as it leaves this reservoir usually contains not more than 3 per cent of water, and in that condition can be taken direct to an oil distillation plant, whilst the ammonia liquor is passed on to the ammonium sulphate plant.

The overall length of a battery, the size shown in the sketch, without chimney, is 52 ft., the width across the brickwork 14 ft. 6 in., and the height to the runner rail of the travelling coal skip 24 in. A battery of this size is capable of carbonizing up to 60 tons of coal per day. If, however, the coal contains a large percentage of moisture, the output of the battery naturally is reduced proportionately.

RESULTS OBTAINED ON LONG RUN

At one of the plants of Low Temperature Carbonization, Ltd., a continuous run was made of 128 days without

intermission, and during this period the following results were obtained—

Coal carbonized . . .	8,280 tons
" Coalite " produced . . .	6,210 tons
" Coalite " crude oil . . .	172,565 gallons
Rich gas . . .	38,502,000 cubic feet of 829 B.T.U. value

This gave an average production per ton of coal carbonized as follows: " Coalite," 15 cwt.; " Coalite " crude oil, 20.9 gallons; and gas, 4,650 cubic feet.

The gas was not passed through scrubbers for the purpose of stripping of its benzol.

At the Barnsley plant of this company various blends of coal are employed from time to time, and below is given a distillation of " Coalite " crude oil obtained from a mixture of Hemsworth slack and gedling slack, which is producing 17½ gallons per ton of coal carbonized. The distillation shows that from this is obtained—

Water	52 gallons =	3%
Light naphthas	52 " =	3%
Creosote	1.63 " =	9.3%
Metacresol and paracresol	1.0 " =	5.7%
Heavy oil (Diesel)	6.57 " =	35%
Crude anthracene	1.75 " =	10%
Hard pitch	56 lb. =	30%

From the gas, by scrubbing with creosote oil, 2½ gallons of crude benzol were obtained. A subsequent distillation of this 2½ gallons produces 1.15 gallons light motor spirit, and 1.15 gallons of white spirit, this white spirit being particularly valuable for liquid metal polishes, dyers, cleaners, etc.

In the " Coalite " crude oil there is no fraction, as a rule, suitable for using in oil lamps fed with a wick, but the creosote is entirely free from all traces of naphthalene, and therefore eminently suitable for use as a wash oil.

There is practically speaking no orthocresol present, but a high percentage of metacresol is obtained, which is of the highest germicidal effect, and also a fair amount of paracresol, which, though not equal to metacresol in its germicidal qualities, is most serviceable as a non-poisonous disinfectant. The metacresol will be most useful for converting into lysol, and can undoubtedly be made equal to any lysol at present on the market.

With reference to the gas, the following is a fair average analysis, previous to stripping for benzol—

	o/o
Hydrogen	22.8
Unsaturated hydrocarbons	4.7
Saturated hydrocarbons	58.2
Carbon monoxide	5.7
Carbon dioxide	3.4
Nitrogen	4.4
Oxygen	0.6
Sulphuretted hydrogen	0.2
	<hr/>
	100.0
	<hr/>

Naturally, the analyses will vary with every kind of coal, but the foregoing may be taken as a fair average, and is an analysis made by Professor Lewes from unpurified gas turned out by a "Coalite" plant in the South of England.

The Maclaurin Process.

This process differs in some respects from others, no external heating of the retort being employed, the coal being carbonized by the combustion of a small part of the coal charge in the retort itself. The retort is built on the principle of a very tall, narrow beehive coke oven, with the temperature under perfect control, and with the recovery of the whole of the valuable gaseous and volatile products, the choking of the draught caused by the installation of a recovery plant being compensated for by the addition of a mechanical forced draught air blast. The fire-brick retort (Fig. 12) resembles an elongated producer or small blast furnace, the overall height being 40 ft., and the width at the zone of maximum combustion, the widest portion, being about 8 ft. The coal is fed in at the top, and the retort possesses the advantage of the intermittent vertical gas retort of the use of gravity in causing the coal to travel downwards through the retort, and the consequent reduced amount of labour necessary. The residual fuel is extracted from the bottom by a special extractor without the use of water, and an air blast, supplied by a small blower, is admitted at the zone of maximum combustion. Part of the fuel is burnt in this portion of the retort, the maximum temperature with usual working being about 1,290° F. (700° C.). The hot gases and volatile products pass

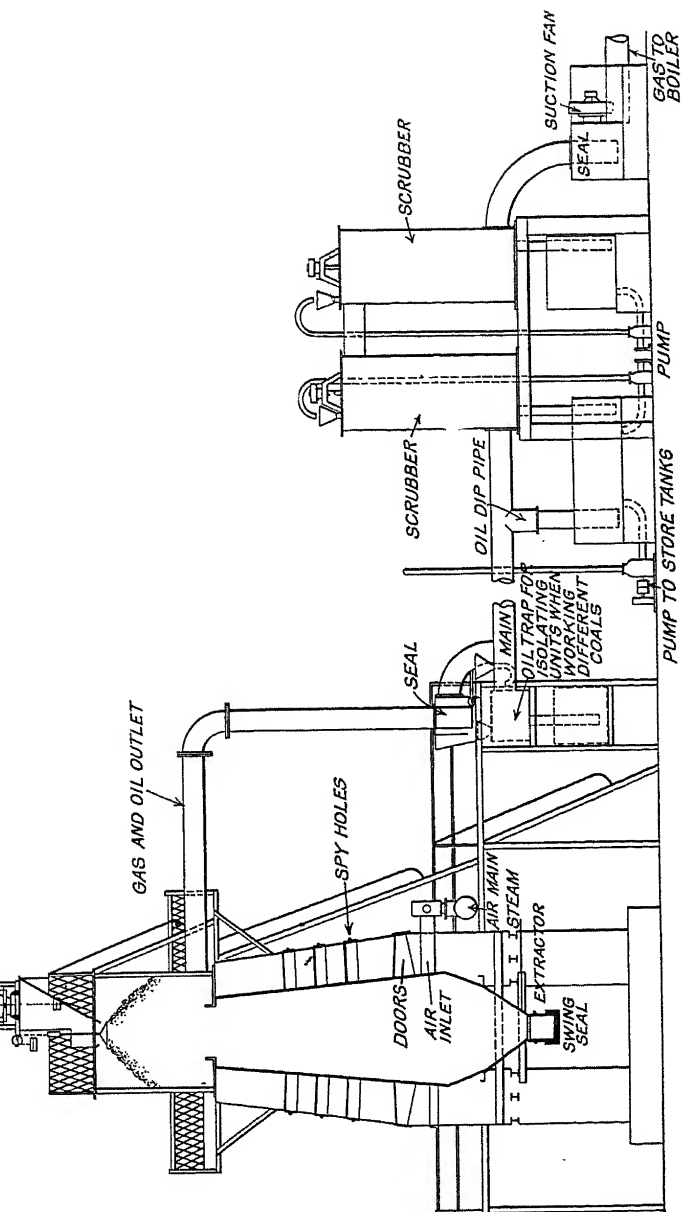


FIG. 12.—THE MACLAURIN RETORT

upwards through the descending fuel, so that there is a slow and gradual carbonization, increasing as the charge descends to the hottest zone. The total time of travel through the retort is 20 hours, the output being at the rate of nearly 1 ton per hour. The oils and volatile products driven off at each succeeding stage of the carbonization pass upwards into a cooler zone, and are condensed in the top layers of practically cold fuel, and the oils are trapped so that they cannot trickle back and pass off along with the gases through a horizontal outlet pipe near the top of the retort. It is found in practice that this slow and gradual carbonization avoids practically all trouble of sticking and jamming, except with very strongly coking coals. This retort is claimed to be particularly adaptable both in the method of working, and in the variety of coals that can be carbonized. The air blast can be regulated according to the results required. Thus with a moderate blast, a dark-coloured, smokeless, easily-ignited, household fuel is produced with 20,000 cu. ft. of gas per ton, but with an increased blast and 30,000-40,000 cu. ft. of gas per ton, the residual fuel is a hard, silvery coke, suitable for metallurgical purposes. The process can also be changed easily to complete gasification. A great variety of fuels can be carbonized, non-coking as well as coking, and low grade and refuse fuels of the right size are stated to present little difficulty, even with 50 per cent ash. The size of the coal carbonized can vary from small nuts to lumps 8 in. to 9 in. cube, but it is not so satisfactory with dross and fine slack. As the heating is external, the total heat losses in the "Maclaurin" process are very small, consisting only of the radiation losses of the retort, the heat in the gases leaving the producer, and the hot residual fuel. The walls of the producer are, however, very thick, and the radiation losses are very small, whilst the gases do not leave the top of the retort at much more than 140° to 175° F. (60 to 80° C.), which reduces the total heat losses to a minimum whilst also minimizing the subsequent work required by the coolers and scrubbers. The following data represent a typical example of the results obtained with a coal containing 35 per cent of volatile matter and 7½ per cent of water. The original coal had a calorific value of 12,300 B.T.U.'s.

YIELD FROM 1 TON OF AVERAGE COAL

(12,300 B.T.U. 35% VOLATILE)

- (1) 27,731 cu. ft. of gas at 247 B.T.U. per cubic foot
- (2) 15.6 gall. oil (dry) of 16,600 B.T.U.
- (3) 15 lb. sulphate of ammonia; and
- (4) 10.96 cwt. of smokeless fuel, as follows—
 - (a) 0.05 cwt. large coke (smokeless fuel), 12,600 B.T.U.
 - (b) 1.16 cwt. smithy char., 12,196 B.T.U.
 - (c) 0.76 cwt. peas, 11,283 B.T.U.
 - (d) 0.99 cwt. breeze or dust, 9,203 B.T.U.

For the production of smokeless household fuel the yield is usually 20,000 to 25,000 cu. ft. per ton of low grade power quality, say, 200 to 250 B.T.U.'s per cu. ft. The following is what may be termed a fair average composition of this quality of gas taken over a 24-hour run—

	%
CO ₂ (carbon dioxide)	6.2
C _n H _{2n} (illuminants)	Nil
CO (carbon monoxide)	16.0
CH ₄ (methane)	13.0
O ₂ (oxygen)	0.6
H ₂ (hydrogen)	16.1
N ₂ (nitrogen)	48.1
Heating value	247 B.T.U. (gross)

The entire absence of hydrocarbons other than methane is noticeable, and is due to the almost complete absence of cracking of the oils during the process of carbonization.

OIL. The oil produced can be taken as 15–20 gallons to the ton, and remains the same with a given coal, irrespective of the method of working the air blast. The composition of the oil is quite different from the ordinary low temperature carbonization oils, since it contains practically no light oils, due to the entire absence of cracking during carbonization, which is characteristic of externally fired retorts. The oil is, however, a true low temperature product in the sense that it has no naphthalene or anthracene. It is characteristic as containing a large percentage of phenols, the lighter distillates containing 50 per cent of cresols and xylenols. There is also a large proportion of high-boiling point 445° to 570° F. (230° to 300° C.) phenols, whilst the distillate over 515° F. (270° C.) contains a considerable percentage of solid paraffins. The crude oil has a heating value of about 16,000 to 17,000 B.T.U.'s per lb., and is very satisfactory as a fuel oil, whilst portions can be used as "Diesel" oil, and also as lubricating oils.

AMMONIA. The yield of ammonia when working the plant on hard coke is 24 lb. per ton, but for ordinary low temperature working the figure is, say, 10 to 20 lb. The ammoniacal liquors are free from ferrocyanides and sulphocyanides, but contain di- and tri-hydroxy phenols dissolved out from the large amounts of phenols in the tar.

SMOKELESS FUEL. With a moderate blast for what may be termed normal low temperature working, the residual smokeless fuel contains about 4 per cent of volatile matter. It is as hard as gasworks coke, but is black in colour and not grey like coke, whilst it is much more easily ignited than gasworks coke, forming, therefore, an ideal household fuel.

It has been found to be very suitable for steam generation. In dealing with low grade fuels with this process, the results shown in the Appendix were obtained.

The "Nielsen" System.

This invention relates to distilling or roasting plant and apparatus which although capable of other application is more particularly adapted for use in connection with methods of medium or low temperature distillation or carbonization, in which a heating medium is employed which is brought into direct contact with the material under treatment.

In methods of low temperature distillation of this character it has been proposed to employ rotary retorts which are of similar construction to the rotary kilns used in the cement industry, and the heating medium is usually constituted by combustion gases obtained from an adjacent furnace. The employment of rotary kilns of this character together with combustion gases from an adjacent furnace results in a very large amount of useful heat being lost by radiation and conduction to the atmosphere, the heat losses being particularly large in that part of the retort where the temperature is highest, that is to say, nearest the source of heat.

In an externally heated retort for gas manufacture and other purposes it has been proposed to employ inner and outer cylinders mounted upon a hollow rotatable shaft which serves as a passage for combustion gases from an external furnace, both the hollow rotatable shaft and the outer cylinder being

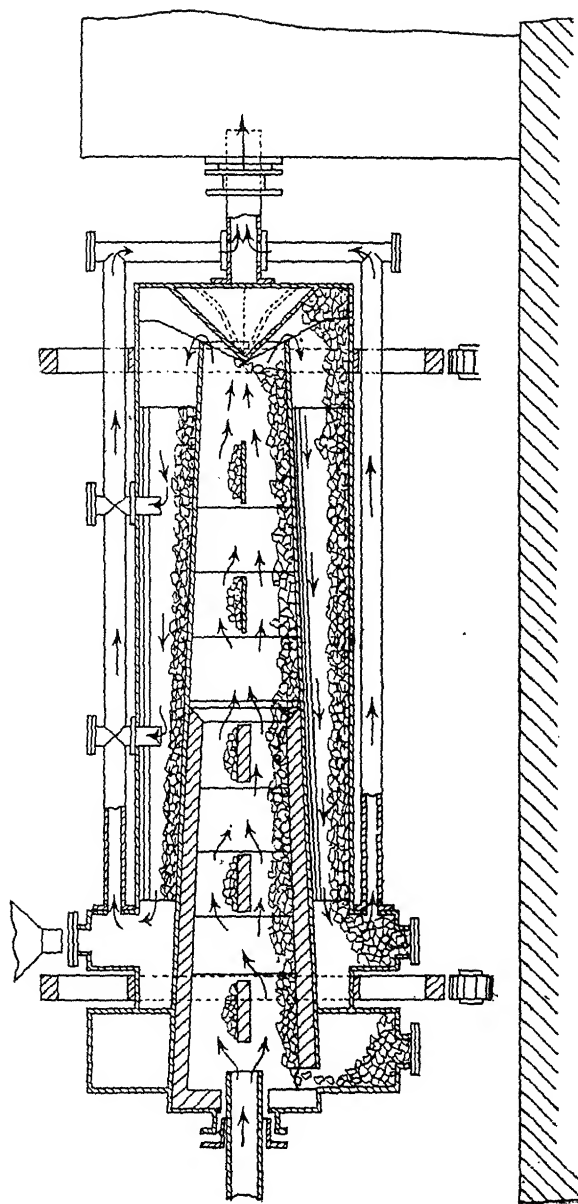


FIG. 13.—THE NIELSEN RETORT

formed with helices on their exterior surfaces, the arrangement being such that when the hollow shaft is rotated the material undergoing treatment is carried through the inner cylinder to the outer cylinder, back through the outer cylinder to the inner cylinder and so on until the treatment is completed.

According to the present invention a retort is employed constituted by two or more tubular members which are arranged around one another in a concentric or similar manner, the material to be roasted or distilled being caused to pass continuously from one end to the other end of the retort between the two tubular members, and then conveyed in the opposite direction along the inside of the other tubular member, the distillation or carbonization being preferably effected by causing the heating medium to enter the retort through the innermost of said tubular members through which it passes in direct contact with and in the opposite direction to the travel of the material under treatment, and thence into the outer tubular member, from which it is led away, together with the products of distillation, for example, by means of suitable offtake pipes or ducts, to a collector which in turn is connected up to a stationary dust separator and to a hydraulic main by means of a stuffing box. Owing to this arrangement it is stated that the usual drawbacks associated with low temperature retorts are dispensed with and distillation or carbonizing can be carried on at a rate which has heretofore not been possible.

The heating medium is preferably constituted by producer gas which is withdrawn directly and without ignition or combustion from an adjacent gas producer, and the so-called sensible or mechanical heat of the unignited producer gas is employed in known manner to effect distillation or carbonization by being brought into direct contact with the material in the retort. As these gases on leaving the producer hold a sensible heat of from 600 to 700° C., the waste heat available therefrom is sufficient to effect the low temperature distillation or carbonization of the material within the retort, with the additional advantage that once they have given up their sensible heat in passing through the carbonization or distillation retort they are still recoverable from the volatile

products of distillation as an unimpaired fuel or power gas (carbon monoxide), etc. If desired, the heating medium together with the volatile products of distillation can be removed from the retort at various points along the outer shell or casing thereof, and conducted to collectors or condensers. The carbonaceous material to be treated preferably enters the retort system through the outermost concentric tube or annulus and is carried forward, for example, by gravity

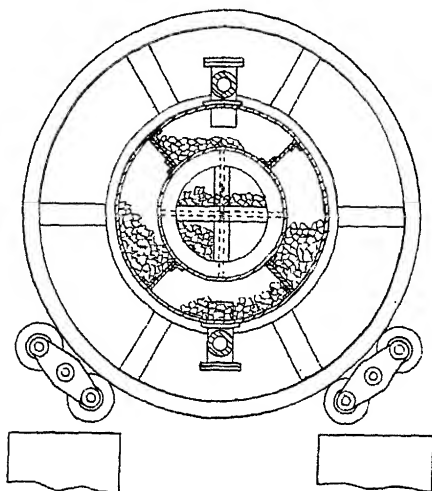


FIG. 14.—CROSS SECTION OF NIELSEN RETORT

due to the inclination and rotation of the retort to the far end thereof where it is picked up by suitable means such as fixed shovels, buckets or plates and conveyed to the inner tubular member which may be of conical configuration in longitudinal section, the side walls of the inner concentric member being also suitably inclined in the opposite direction to the outer member. The carbonaceous material within the inner concentric conical tube is thus caused to travel in the opposite direction to that in which it is passed down the outer tubular member, and also in a contrary direction to the heating medium. As the carbonaceous material travels down the concentric tubular members it passes through zones of gradually increasing temperature and the final stages of carbonization

distillation take place in the inner annular tubular member, where the heating medium enters.

The innermost tubular member may be fixed to the outer member (or members) by means of plates and angle irons so that the members form an integral whole. These plates may be solid or perforated and they may be arranged in such a manner that the annular space between the inner and outer tubular members is divided longitudinally into two or more continuous channels, or the plates may be short and staggered relatively to one another so that the annular space between the tubular members is divided up into more or less screw-like channels.

It will be understood that the carbonaceous material contained in the channels which are so formed is carried by the rotation of the retort to the upper regions thereof where the heating medium preferably travels and is brought in turn into intimate contact therewith, the sensible heat of the heating medium being thereby utilized in the most effective manner.

As a further alternative a continuous helix or screw may be provided along the interior surface of the outer tubular member or on the exterior surface of the inner tubular member, and also if desired along the interior of the inner tubular member so as to secure a positive feed of the carbonaceous material from end to end of the retort. With such an arrangement the concentric tubular members may be cylindrical and a positive feed ensured by the relative rotation of the inner and outer tube.

If found convenient, the inner retort tube may be provided with shelves stretching across the same in order to carry the carbonaceous material up to the crown of the tube, thereby promoting a still better contact with the heating medium. The carbonized material may be intermittently or continuously discharged into an annular collecting box fixed to the outer retort tube, from which box the carbonized material can be removed from time to time.

The charging of the raw carbonaceous material can preferably be effected intermittently through charging doors situated in the outer retort tube, and the retort supported by rollers and revolved or rotated by any well-known means.

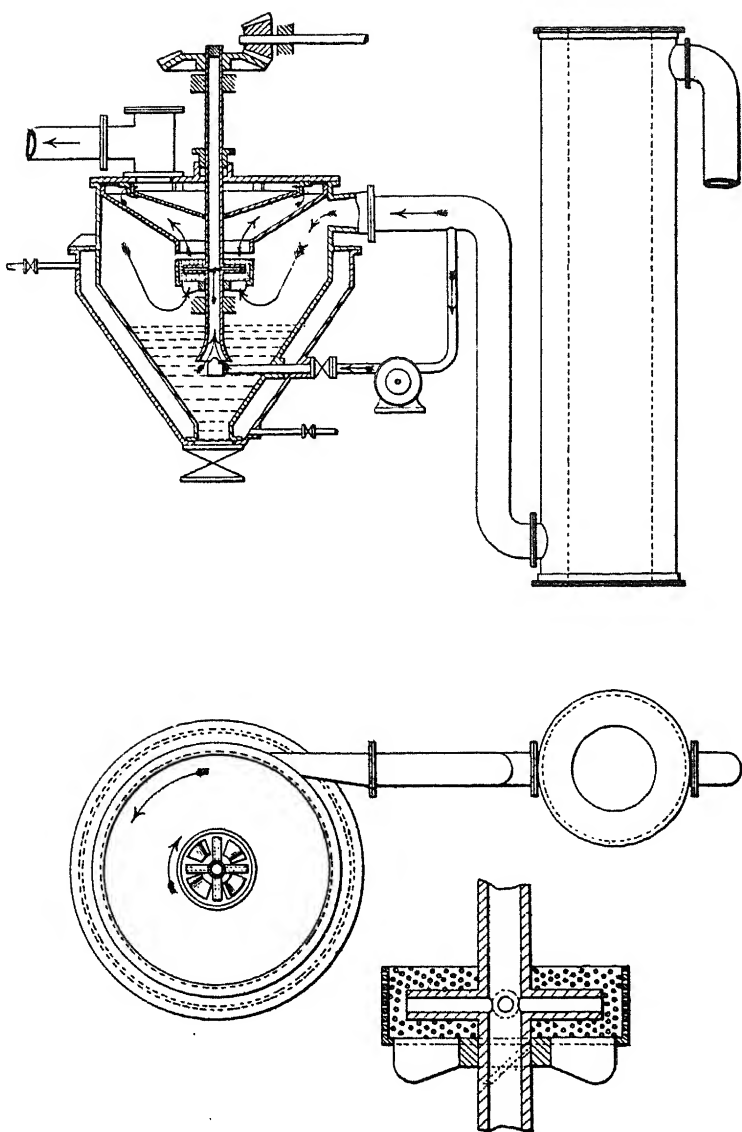


FIG. 15.—THE NIELSEN RETORT GAS EXTRACTING APPARATUS

In order that the invention may be clearly understood reference should be made to the accompanying drawing, which shows by way of example one embodiment of the invention and in which Fig. 13 is a longitudinal section of the improved retort and Fig. 14 is a cross section of part thereof. The gas extracting apparatus is shown in Fig. 15.

Owing to this construction and arrangement of the parts of the retort the heat usually lost by radiation from the hottest zone, that is to say the inner tubular member, is conserved and made use of in the outer annulus by direct conduction to the carbonaceous material contained within the same. As, therefore, the outer surface of the retort, where the real heat losses by radiation to the atmosphere takes place, has only a very moderate temperature the heat losses within the retort itself are very small, and the outer tubular member serves in fact as a heat jacket for the inner tubular member. Furthermore, it will readily be understood that by employing a retort as aforesaid containing as in the example given one inner tubular member, the overhall length of the retort is only one-half of that of a single retort with the same length of travel of the carbonaceous material and consequently the radiation surface through which heat losses can occur is greatly diminished.

The Plauson Process.

This process claims to recover the products from carbonaceous materials at a temperature below the boiling point of the organic component parts, and below that of decomposition. It is stated that the driving off of the products takes place by mechanical action instead of by distillation. Superheated steam or inert gas is sprayed through nozzles, penetrating the layers of material, and carrying off products having a high boiling point. The temperature at which the process is worked is about 350° C. The details of the apparatus are shown in Figs. 16 and 17.

The vertical cylinder is filled with material, e.g. oil shale in pieces from nut to fist size. About 1 to 1½ metres below the top there is a ring-shaped device in which a plurality of nozzles are mounted like those used for steam turbines. These

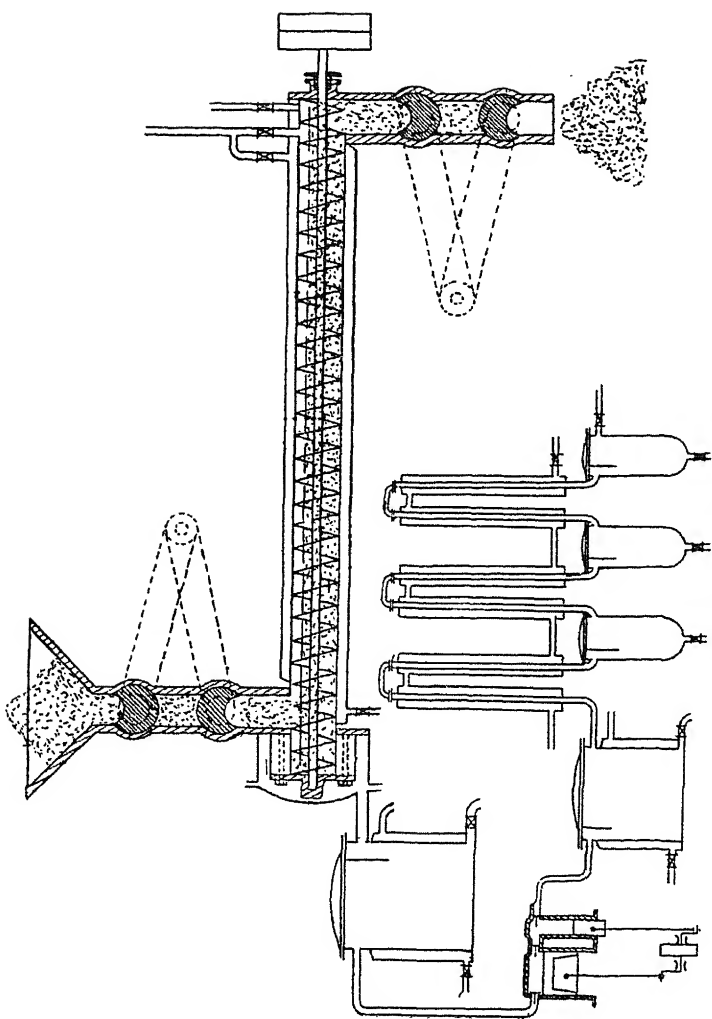


FIG. 16.—THE PLAUSON RETORT (HORIZONTAL TYPE)

nozzles can be directed obliquely inward and are fed by a common feed pipe. From these nozzles the steam will expand to a velocity of about 500 metres per second and thus act upon the material. The layer may be about 20 centimetres to about 1 metre, depending on the type of material used. The steam is removed through one or more rings of slits protected by wire netting, from which the steam is led off in suitable manner. The entrained material is collected as hereafter described.

The material is preferably continuously fed to the vertical cylinder through the device shown, freed from the volatilizable material in the middle, and continuously removed by the worm through the outlet. The lower part of the cylinder between the ring of slits and the worm can be provided with a water jacket to cool the material from which the oil has been removed. This preheated water is preferably used for feeding the boiler. The velocity of the steam can be increased by employing a vacuum in the condensation space.

The cylinder can be arranged in other positions than the vertical, e.g. Fig. 16 shows a horizontal cylinder, in which the material is continuously removed by the worm. A single large nozzle is provided, and the volatilizable material is removed with the steam at the outlet tube, after which it is suitable treated for condensation. The material is introduced through the device shown. Fig. 16 diagrammatically illustrates a complete installation. The boiler generates steam at a pressure of 15 to 20 atmospheres. This steam is passed through a non-return valve to the steam engine, provided that there is no super-pressure in the compressor. If the latter is the case, the non-return valve closes automatically. The high-pressure steam is passed through the superheater to the cylinder space of the engine, in which it passes through the pipes in the usual manner. The dimensions of the steam engine are such that an exhaust of about 10 atmospheres super-pressure leaves the cylinder. This steam now passes through a pipe to a set of superheaters, in which it is heated to about 400° to 500°, and then through a regulating valve to the nozzle in which it expands. In this way the

energy of the steam is largely converted into free kinetic energy and the steam flows at very high velocity laterally into the vessel on whose lid is provided a device which changes

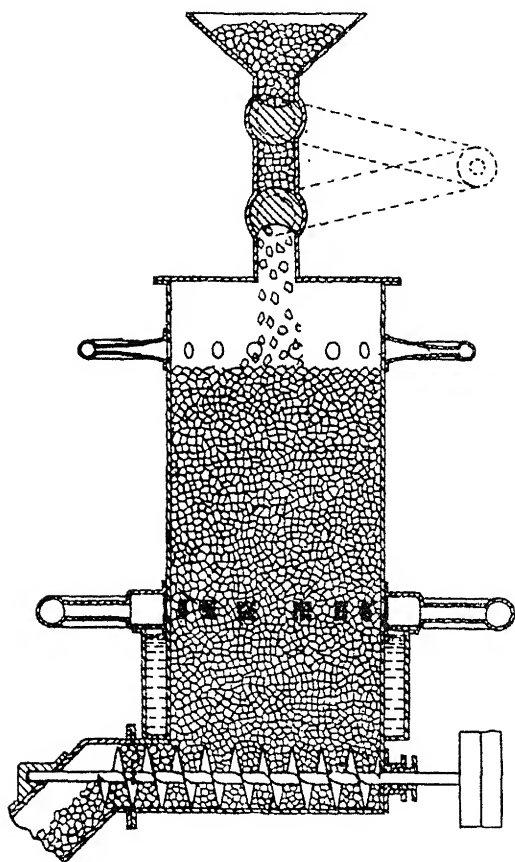


FIG. 17.—THE PLAUSON RETORT (VERTICAL TYPE)

the direction of the steam current so that it flows through the material to be treated, e.g. oil shale. This device preferably consists in a removable curved member so that fresh material can be charged into the cylinder in the simplest possible way. The exhaust passes from the cylinder and the greater part of the entrained oil collects in the space shown

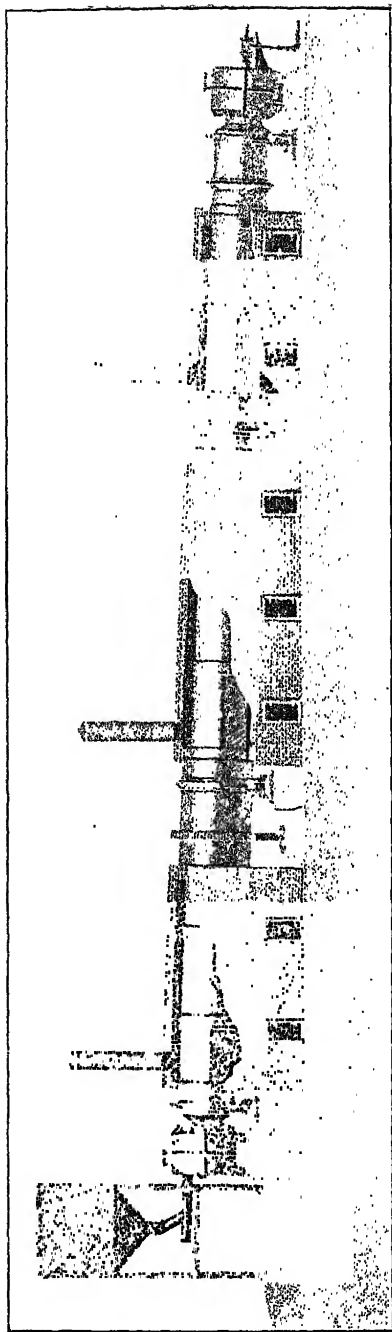


FIG. 18.—THE RANDALL RETORT

and flows through the cooling pipe, which is cooled with water or a cooling fluid in the collecting vessel. The uncondensed steam with the fractions of lower boiler-point leaves the space through an expansion nozzle from which it again expands and passes into a separating vessel. This nozzle is preferably so arranged that when the steam expands it is set in rotation in the direction of the arrows, so that a vortex movement is caused which materially facilitates the separation of the oil. If necessary, suitable chemicals can be added in this vessel in order to separate out impurities. For example, sulphuretted hydrogen is removed by injecting a dilute solution of a lead salt. The condensed portions flow through the cooling pipe into the collecting vessel. Further, the steam passes through the pipes to a third superheater and then to the compressor through one of the valves. The steam is again compressed and preferably to a somewhat higher pressure than that prevailing in the boiler. The compressed vapour passes through one of the valves and then through a valve before the superheater or to another valve after the superheater, depending on the temperature; the steam is passed again into the high-pressure pipe and again enters the cycle. Such a cycle saves a considerable amount of steam, since the same steam is used continually, while losses of steam by condensation are replaced from the boiler through the non-return valve.

The Randall Retort.

The Randall process is a rotary retort, not unlike a cement kiln (Fig. 18). If, as in cement-kiln practice, internal heating could be used, this retort would, says Dr. David T. Day, no doubt provide a very desirable method of oil-shale distillation. If internal heating is not used the rotary kiln loses its efficiency and presents serious mechanical and structural difficulties. The design of this retort is on similar lines to the Fusion, which followed it. The latter, however, includes a device for breaking the coal, etc.

The Salerni Retort.

In this design stirring or agitating devices are provided and located within a retort chamber which is preferably heated

externally, the said devices being so constructed and arranged that they serve primarily to stir or agitate the material either without propelling the same through the retort chamber or else only propelling the same through the retort chamber to an incidental extent and at a very slow speed, thus permitting the carbonaceous material to remain sufficiently long in the retort for the valuable volatile constituents to be yielded up. Owing to this arrangement the stirring devices, or the retort, can be rotated with the minimum expenditure of power at any suitable speed independently of the speed at which the material is fed through the retort chamber, so as effectually to stir the material within the retort and expose fresh surfaces to the action of the heating medium. The stirring devices may be constituted by a number of radial arms or blades disposed at suitable distances apart along the length of the retort chamber, the said arms being mounted upon a shaft which is rotated at any desired speed from any suitable source of power. The successive blades or series of blades can, if desired, be staggered or displaced relatively to one another, so as to present a star-like appearance in end view. Instead of rotating the stirring devices relatively to the retort, the stirring devices may be stationary and the retort may be of any well-known revolving type or rotary type, the retort gases being drawn off from one end of the retort.

Fig. 19 shows the retort chamber, which in the example shown is composed of metal and located within a brick setting, the retort being heated externally by means of a gas furnace, which is arranged for the graduated heating of the retort throughout its length. The shaft is located centrally in the retort chamber and extends from end to end thereof, the shaft being adapted to be retorted from any suitable source of power. The stirring devices are disposed along the retort chamber and are mounted upon the shaft. The stirring devices are composed (as shown) of radial blades, and the several sets of radial blades are suitably placed apart from one another and held in position on square portions of the shaft by means of collars. The hopper leads to the retort chamber through which the material to be treated is fed, a rotary feed valve being provided which is driven at a suitable speed

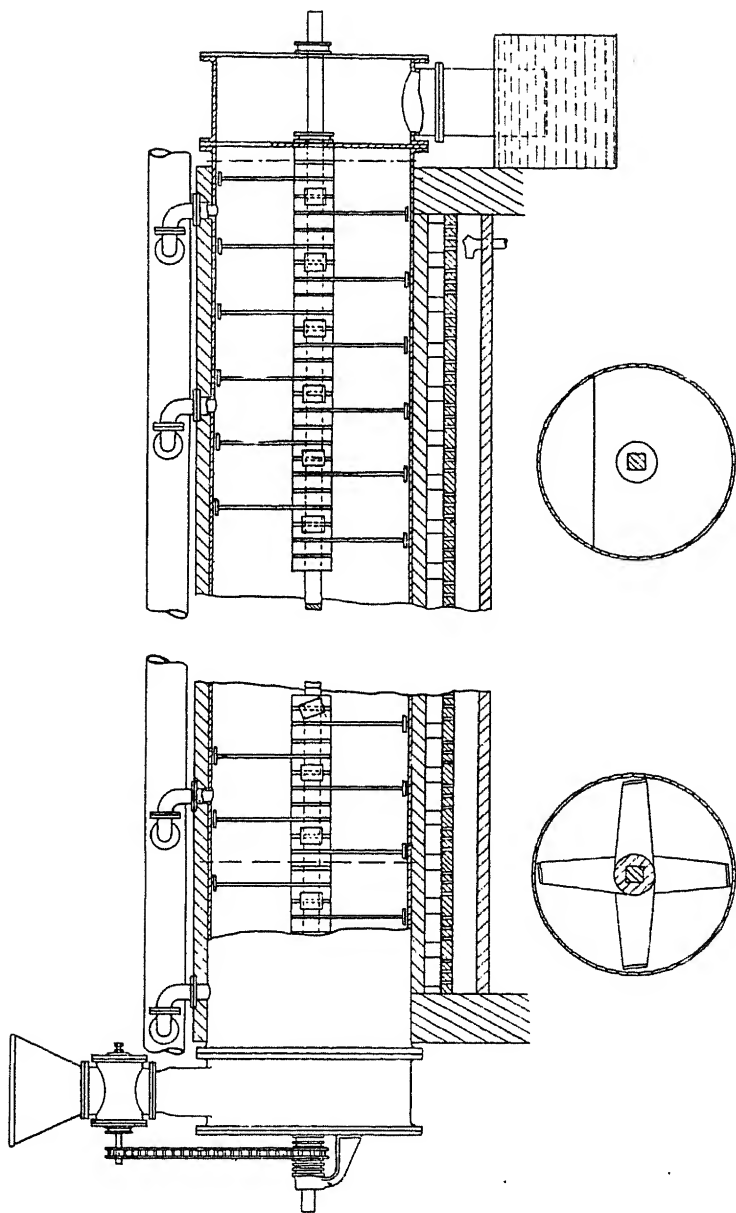


FIG. 19.—THE SALERNI RETORT

from the rotating shaft by means of a chain and gear wheels. A baffle plate is disposed towards the outlet end of the retort chamber, the plate being adapted to maintain a suitable depth of material within the retort chamber, while the surplus spent material which has undergone treatment is adapted to be discharged through the opening between the upper part of the baffle plate and the top of the retort. The spent material discharged over the baffle plate falls through an outlet into a water seal. Outlet pipes are placed at suitable distances apart along the upper part of the retort chamber; the volatile constituents yielded up by the heat treatment of the carbonaceous material being withdrawn at approximately the zones where they are given up through pipes into a common conduit from which the volatile gases are conducted to a condenser. In the example shown the radial arms are provided at their outer extremities with scraping devices which serve to remove any material which may tend to adhere to the inside of the retort chamber. In cases where it is desired to give a slight propelling action to the material the scrapers may be suitably twisted or otherwise formed so as also to serve to propel the material at the periphery only of the retort. For example, the scrapers may be slightly inclined in a vertical plane as shown in sketch, and also if desired in a horizontal plane, as shown in Fig. 19. Owing to the fact that the propelling movement, when such is provided for, is applied only at the periphery of the mass of material undergoing treatment the forward thrust is relatively small and does not result in any substantial increase in the speed at which the material passes through the retort chamber. If desired, the retort may be slightly inclined from the inlet to the outlet end to facilitate the passage of material from one end of the retort to the other. In operation the material which is to undergo treatment is fed into the retort chamber through the feed valve until the retort is filled to the level of the top of the baffle plate. The stirring devices during their rotation tend to maintain the material at this level throughout the length of the retort chamber, and the material is thoroughly stirred or agitated. Once the retort has been filled to the level of the top of the baffle plate the rate of discharge of spent material over the top of the

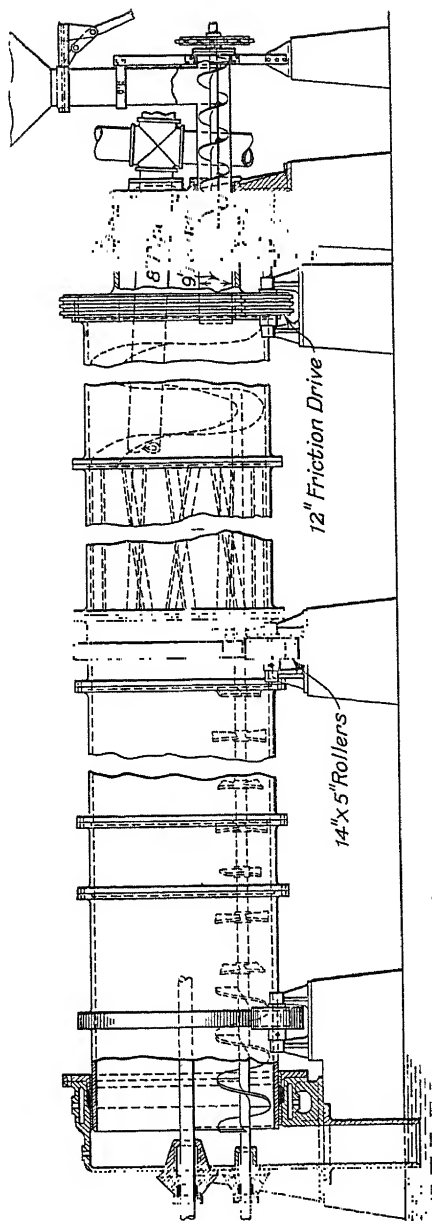


FIG. 20.—THE SPENCE RETORT

baffle plate is regulated by the quantity fed into the retort chamber, as any additional material above this level will discharge itself automatically over the top of the baffle plate into the water seal. The charge of material can therefore be retained within the retort for any desired length of time and until the distillation is completely effected and agitated or stirred at the most effective speed during such treatment.

The Spence Retort.

This retort is fashioned after the well-known rotary lime or cement kiln, in that the body of same consists of a long steel cylinder, which is caused to rotate in an inclined position on trunnions. This cylinder or shell is provided with a suitable driving gear to cause it to rotate at a predetermined speed. The ends of the shell pass into stationary chambers through patented sealing devices which prevent the egress of oil vapours and the ingress of air. Provision is made to feed continuously in ground shale through the upper stationary chamber and remove the "spent" shale through the lower one. During the passage of the shale through the retort it is subjected to predetermined and definite degrees of heat, so that the various volatile products are driven off from the shale as quickly as they are formed. In this manner, the "light" hydrocarbons do not come within the influence of higher temperatures than those at which they are formed, so minimizing the quantity of fixed gas formed with consequent loss of oil. The vapours formed within the retort are exhausted through suitable air and water-cooled condensers as rapidly as they are evolved.

The fuel used to heat the retort is usually gas, part being the fixed gas evolved with the vapours and the balance produced directly from either raw or spent shale in a standard gas producer. The heat is applied in an indirect manner in three bricked-in fire-boxes, so that the "live" flame never comes in direct contact with the steel shell. However, provision is made in the construction of the retort so that practically the whole of same is under the influence of the heat. This special construction eliminates the otherwise lost heating surface at the sections where the driving gear and tyres are

placed. Further, provision is made in the retort to treat the shale during distillation with steam or other fluid to affect the vapour tension and reduce the temperature at which the oil vapours are formed. The effect of this can be readily seen in its influence on the quality and quantity of oil produced, the general wear and tear of the apparatus and fuel economy. The steam or other fluid is passed through the shale and not over; reducing temperature 150° F.

The shale is thoroughly agitated during its passage through the retort (Fig 20) so that all particles come in intimate contact with the heated shell. Pyrometer fire ends are arranged at a number of points within the retort so that the heat may be properly regulated to ensure best results.

The distillation results were very satisfactory. The density of the crude oil obtained was about 30° B. ($\cdot 875$), and upon distillation 75 per cent by volume up to 275° C. was obtained. This distillate on refining yielded a water-white oil of 47° B. ($\cdot 7909$). In another instance the crude was distilled to an end point of 210° C. for motor fuel and 42 per cent by volume was recovered of 56° B. ($\cdot 7526$). The gasolene is said to have withstood the United States Navy tests for domestic aviation fuel with the exception of the first low boiling point.

This retort is on similar lines to the Randall and the Fusion retorts.

The Tozer Retort.

The Tozer retort (Fig. 21) consists essentially of an annular retort capable of being heated internally and externally. The maximum thickness of fuel employed between two heated surfaces in actual practice would appear to be 4 in. The retort is made of cast iron set vertically. If a single annulus were employed, the cubic contents would be comparatively small, but the inventor claims that by making use of radial cast iron fins it is possible to employ two or more concentric retorts, thus increasing the fuel capacity. It is claimed that the heat which is applied to the exterior and the interior faces is conducted along the cast iron radial ribs and spread concentrically by means of the cast iron cylinders, so that although

the actual thickness of fuel between directly gas-heated surfaces may be 8 or 12 in., nevertheless, owing to the arrangement of metallic conductors, no portion of the fuel is more than 2 in. removed from an actual heating surface. By

making the retort of slightly greater diameter at the discharge end, it is claimed that no difficulty is experienced, even with coals which swell excessively on coking, in getting a free discharge. The cylindrical shape employed is mechanically strong, and those fuels which tend to expand on coking at the earlier stages of the process are restrained by the strong iron walls, with the result that the compression arising leads to the production of a hard coke, and the polished surface of the coke discharged from these retorts gives evidence in support of this contention. Owing to the fact that the expansion during coking is followed by a contraction, and even at the low temperature employed, namely, 400° to 500° C., this contraction period has already been entered into, there does not appear to be any tendency for the coke to hold up in the retort. It has been found that bituminous shales which expand when the volatile matter is driven off, do bind because the expansion in this case is not followed by a subsequent contraction. In the earlier stage of the development of the Tozer retort con-

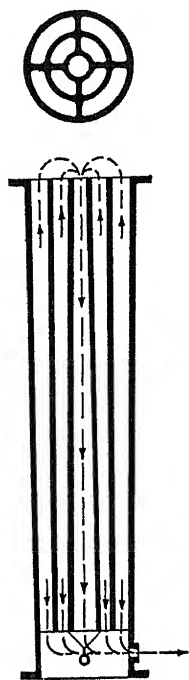


FIG. 21.—THE
TOZER RETORT
(Sectional view)

siderable weight was laid upon the advisability of working under a high vacuum, and a vacuum of 26 and 28 in. of mercury was freely mentioned. Those who have had experience of working any plant of considerable dimensions under such a high vacuum will realize the difficulties that would be involved in the constructions of joints which have to be frequently made and remade, and which are subjected to a temperature approaching a visible red heat. To this must be added the very considerable power that is involved in pumping away

EXTRACTS OF RESULTS OBTAINED BY THE TOZER SYSTEM OF LOW TEMPERATURE CARBONIZING AT A TEMPERATURE UNDER 1200° FAHR.

NAME OF COAL.	ANALYSES.						YIELDS PER TON OF COAL CARBONIZED.							
	COAL.			TARLESS FUEL.			A Spirit.	Light Oils.	Heavy Oils.	Total Oils.	Tar Acids, Cresylic.	Pitch.	Sulphate.	Tarless Fuel.
	H ₂ O.	V.M.	F.C.	Ash.	N.	H ₂ O.									V.M.	F.C.	Ash.	N.
Ballengleich (Natal)	3.34	25.10	53.65	19.0	—	3.7	9.85	63.11	23.34	—	—	—	—	—
Forest of Dean	3.1	31.2	58.57	7.0	—	dry	12.9	78.4	8.7	—	—	—	—	—
Hulton	—	—	50.06	7.21	—	dry	8.26	82.85	8.89	—	—	—	—	—
Malby Main	13.0	29.2	—	8.9	—	—	—	—	—	—	—	—	—	—
Silkstone, Beaushaw	—	30.9	—	—	—	—	—	—	—	—	—	—	—	—
Silkstone, Winter Slack	dry	32.85	58.31	8.84	—	dry	8.0	81.6	10.4	—	—	—	—	—
Silkstone, Two Foot Slack	dry	32.96	57.39	9.65	—	dry	7.71	82.3	9.99	—	—	—	—	—
Niddrie Cannel	dry	50.87	44.4	4.73	—	—	8.08	75.52	16.4	—	—	—	—	—
Newbottle Cannel	dry	50.23	44.06	4.33	—	—	—	—	—	—	—	—	—	—
Hucknall Belt Pickings	1.14	21.2	43.7	31.0	—	—	—	—	—	—	—	—	—	—
Sulphide Corporation (Australia)	3.8	31.8	55.9	8.43	1.75	—	10.3	75.4	18.26	1.95	5.37	—	—	—
Bignall Hill Washed Pearls	2.08	—	—	5.4	—	—	—	—	7.4	—	2.5	—	—	—
Tilmanstone (Slack) Kent Coal	—	—	—	—	—	—	—	—	—	—	2.5	—	—	—
Snowdon (Kent Coal)	—	—	—	—	—	—	—	—	12.5	—	2.5	—	—	—
Stanton Iron and Coal Company (Cannel)	—	—	—	—	—	—	—	—	13.8	—	3.0	—	—	—
Wigan (Cannel)	—	—	—	—	—	—	—	—	—	—	7.6	—	—	—
Lignite (Spanish)	1.64	57.82	36.61	3.93	—	2.25	7.96	82.77	7.02	—	6.8	—	—	—
Shale (Spanish)	5.24	35.74	—	9.99	1.30	—	12.50	15.60	—	—	1.24	—	—	—
Glapwell (Slack)	—	—	—	—	—	—	—	—	—	—	2.2	—	—	—
Glapwell (Nuts)	—	—	—	—	—	—	—	—	—	—	1.1	—	—	—
Tyne Boghead Cannel (Mickley)	—	—	—	—	—	—	—	—	—	—	3.54	—	—	—
	—	—	—	—	—	—	4.30	5.03	5.40	17.06	13.0	—	—	—
	—	—	—	—	—	—	—	10.17	8.39	28.09	—	—	—	—
	—	—	—	—	—	—	—	14.9	19.94	53.5	—	—	—	—

NOTE.—In addition to the production of spirits (petrols) obtained from the fractionation of the tar oils, an additional 2 to 4 gallons per ton of coal carbonized will be obtained by "stripping" the rich gas which must be added to that tabulated in this statement under Column A.

COXES.—The coxes contain from 7 per cent to 12 per cent of volatile matter.

TAR OILS.—These fractionate into tar acids (cresols), and represent (approximately) 7 per cent to 14 per cent of the crude oils. The oils contain 5 per cent to 8 per cent of paraffin wax.

4,000 to 5,000 cu. ft. of gas per ton of fuel treated under such a high vacuum.

That the use of a vacuum will result in the more rapid removal of the products of distillation from the hot zone is obvious, and the benefits that would arise from this in the case of high-temperature retorts is clearly very great, but it is not equally obvious what great benefit can arise in a case where the gases cannot under any circumstances be subjected to a sufficient temperature to cause any appreciable amount of pyrogenetic decomposition.

The Trent Process.

This process, although adopting certain principles inherent in other systems, differs in the application of these. The rotation of the material is common to one or two other plants, but in the Trent, the hearth structure is used, through which the material passes from the top to the bottom. The movement is delayed in its progress in such a manner as to spread the material over a larger surface, and a conveyor is employed which is so constructed that instead of diffusing the material, it is compacted, while during this process, the heating effect is not much more than is necessary to counteract the colder temperature of the metal of the conveyor.

The apparatus consists of a retort having suitable walls, mounted in any approved manner upon the base. Supported within the retort, upon an inner casing is a plurality of circular, double-walled, hollow, stationary hearths, which may be composed of metal, and each hearth has its upper and lower surfaces disposed at an angle so as to merge at the inner termination thereof in a circle, so that in section it shows as a point. Both the inner casing and the outer wall of the hearth are formed so as to provide flues on opposite sides of the retort (Fig. 22) for the passage of heating gases. Positioned within the flues is a plurality of spaced baffles serving to deflect the heating gases and cause the gases to pass into the open portions of the hearth. It will be observed that the stationary hearths are hollow in formation so as to provide a passage for heating gases whereby the surfaces of said hearths are exposed to heat for the treatment of materials. The heating gases may

be introduced to the retort through a feed pipe which is provided with branches, for introducing the heating gases to both the stationary and the rotary hearths. Rotably mounted within the retort is a hollow column, seated within bearings at one end, and the structure is provided with sand seals at each end of the column for preventing the escape of the heating gases introduced therein. Carried by this column is a plurality of baffles adapted to deflect the heating gases so as to cause them always to pass in a circuitous path into the hollow interiors of the rotary hearths, which are of substantially the same general arrangement as the stationary hearths, and are mounted on column. The rotary hearths are in form the reverse of the stationary hearths, the inclined upper and lower surfaces merging at their outer terminations, thus providing a passage for the material, between the rotary and stationary hearths, which are substantially equi-distant from one another at all points. The rotary hearths are hollow to provide passages for the incoming heating gases, the gases being also introduced into the interior of the stationary hearths through openings communicating with the gas flues. These gases are conveyed to the retort at the lower end thereof and travel upwardly through the retort in a direction counter-current to the path of the material introduced thereto, finally discharging through the flue discharge, providing in the retort regions of different temperatures. The rotary hearths may be rotated in any approved manner, as by mounting upon the lower end of the column a gear, which meshes with a worm for rotating the column, and in turn all the hearths rigidly connected thereto. The column at its upper end is connected with a feed pipe extending loosely through the connection having a suitable packing therein, and it is through this feed that material is introduced from a supply pipe by a pump or the like. The material to undergo treatment is introduced through the supply pipe into the passageways formed between the various stationary and rotary hearths and progressively travels downwardly through the retort while being subjected to the heat of the gases introduced through the gas feed. The material is first deposited upon the inner part of the surface of the uppermost rotating hearth, passing between the hearth and the upper

inner surface of the retort, which retort wall is furnished with rabbles, then around the point of the upper rotary hearth, and then deposited upon the surface of the succeeding stationary hearth, travelling in this manner throughout its passage through the retort. To prevent, if desired, agglomeration of solid particles when a pulverized material is being treated, upon the bottom surface of each stationary hearth a plurality of hollow rabbles is placed, which serve to keep the moving material in a constant state of agitation and also to transmit heat thereto while the material is passing over the surface of a movable hearth. These hollow rabbles may be, if desired, in free communication with the interior of the hearths and derive heat from the heating gases flowing therein as indicated. To prevent agglomeration of the material while travelling over the surface of a succeeding stationary hearth, rabbles are provided attached to the lower surfaces of the rotary hearths, which constantly agitate these materials and also transmit heat thereto. The rabbles may be spaced varying distances from one another so as always to cause the material passing over the hearth to be moved in the passage-way, thereby preventing accumulations of the material between the rabbles on either hearth. These rabbles may be set at varying angles, and the position and number of rabbles depends upon operating conditions. The material when introduced is compelled to pass entirely through the retort, over the alternate stationary and rotary hearth surfaces, through the passage-ways, and as a result of the counter-current travel of the heating gases, the material is subjected to a progressively increasing temperature, which is highest at the point where the material is being discharged. With a view to separating and segregating the vapours of oils of different boiling points, an apparatus, shown in Fig. 23, is provided, in which independent vapour take-off pipes are connected to different parts of the retort, each pipe preferably leading to a separate point of collection and storage. Any number of these discharge pipes may be employed, and they may be disposed in any manner desired. It will be appreciated that the heated gases indirectly heat the material passing through the retort by conduction through the exposed surfaces of the movable and stationary

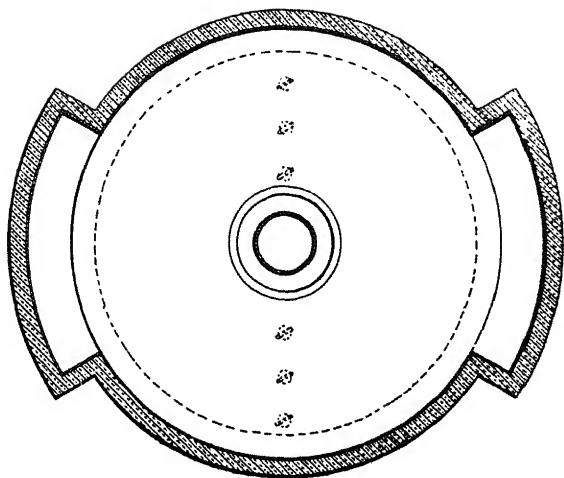
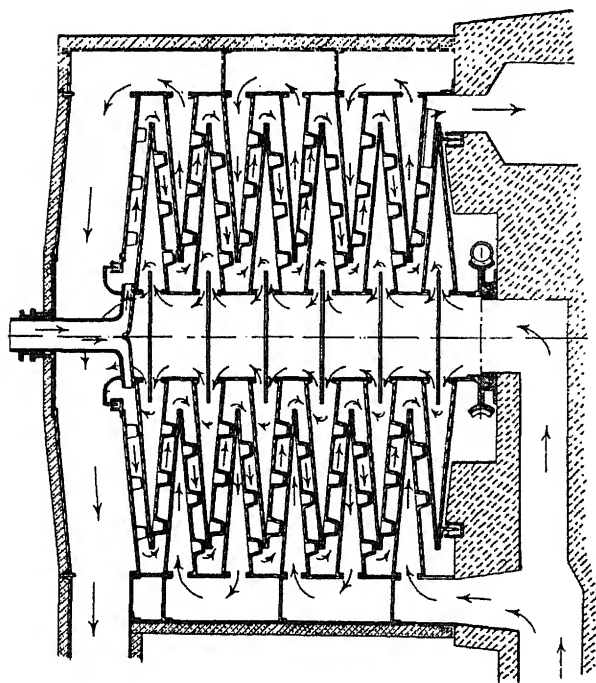


FIG. 22.—THE TRENT RETORT

hearths. The material is in a state of movement and agitation when passing through the retort so that in the event of a material such as comminuted coal being treated, the residue is discharged from the retort by the elongated deflector attached to the lower stationary hearth, and is collected in the receiver in the form, if so desired, of finely divided carbonized particles which have not agglomerated or fused together. In practising the invention for the recovery of a maximum yield of light oils

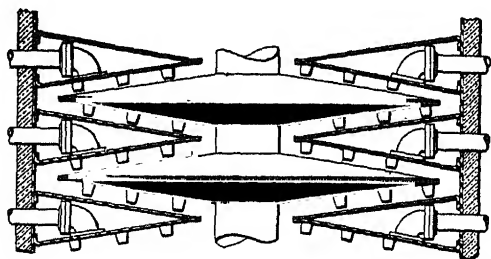


FIG. 23.—ARRANGEMENT FOR SEPARATING THE VAPOURS IN THE TRENT RETORT.

and other by-products from pulverized coal, the coal is introduced to the retort and subjected to a gas temperature of approximately 450°C . or less, which is sufficient to distil volatiles from the coal particles, and inasmuch as these coal particles are kept in a constant state of agitation the temperature is not sufficiently high to cause a material agglomeration thereof. The degree of fineness of the material controls to a certain extent the temperature necessary and the time required to remove the volatiles. When coal ranging between 100 to 200 mesh (i.e. capable of passing through a screen having from 100 to 200 meshes per sq. in.) is treated, the desired result can be obtained with a gas temperature not higher than approximately 450°C ., with a treatment of approximately 30 minutes. The applied heat or gas temperature being approximately 450°C ., the temperature actually imparted to the material is approximately 350°C . By treating the coal while in a very fine state of division, under agitation and at a low temperature, a maximum quantity of light oils is recovered

from the coal with a minimum percentage of fired gases. This is possible only because of the low temperature treatment and the fineness of the material for reasons previously pointed out.

The Universal Retort.

This retort can be utilized for complete gasification or for the production of smokeless fuel. It could probably be adapted for the production of hard metallurgical coke.

It is a vertical retort, and was originally designed for carbonization at low or medium temperatures, with the object of producing gas distillates and coke (smokeless fuel) in varying ratios (Fig. 24).

According to this figure, the apparatus consists of a vertical cast iron tube (*a*) slightly tapered, placed with its larger end downwards on a firebrick setting (*b*). The firebrick setting is so shaped as to constitute an extension of the bore of the tube for a further length equal to about one-third of the length of the tube. From the point where the tube joins the firebrick setting an external firebrick casing (*c*) is built up around the tube (*a*) for nearly the whole of its length, and is so arranged as to leave an annular space (*d*) around the tube. Four or more gas burners (*e*) are arranged to project through the firebrick (*c*) towards the tube (*a*) for the purpose of heating it externally. On the top (small end) of the tube is mounted an annular cast iron trunk (*f*), forming a collecting chamber, with its near side so cut away as to provide an opening into the tube. A pipe (*g*) is connected with this trunk to convey away the volatile and gaseous products, liquid and semi-solid products collected within the trunk (*f*) being prevented from falling back within the inner retort shaft. On the top of the trunk (*f*) is mounted a hopper (*j*) with a gas-tight lid (*k*) and a bottom valve (*l*), which is operated by a lever (*m*) for the purpose of feeding the tube with the material to be treated. A platform (*n*) may be fixed around the hopper for convenience in charging.

Beneath the firebrick setting at the lower end of the tube is fixed a horizontal cast iron box (*o*) of rectangular section, having a circular hole (*p*) in its top side, of the same diameter as the hole formed by the firebrick setting with which it

coincides. At one end of the iron box (*o*), and in its bottom side is another hole (*q*) of about the same area as the first mentioned.

Within the iron box is a hollow iron ram (*r*), coupled by rods or bolts to an iron block (*s*), and so arranged that a space (*t*) exists between the ram and the block. The block follows the ram in its movements to and fro in the iron box or casings.

The ram is operated by a horizontal screw (*u*), which projects through one end of the iron box and is driven by gear wheels (*vw*). The gear wheels are driven by a shaft, on which is mounted a fixed pulley (*x*) with a loose pulley on either side of it. These pulleys are driven by belts from any convenient source of power and are so arranged that normally one belt rotates one loose pulley in one direction while the other belt (which is crossed) rotates the other pulley in the opposite direction. A fork or guide is arranged to move the belt alternatively on to the fixed pulley at predetermined times, thus giving a clockwise and counter-clockwise motion to the gear wheels and therefore a reciprocating motion to the ram (*r*) within the box or casing.

At each end of the box or casing (*o*) is fixed conveniently a trigger, the two triggers being coupled by rods and balance weights to the belt forks in such a manner that when the ram has travelled the required distance within the casing it operates one of these triggers, which in turn moves the other belt on to the fixed pulley and thus reverses the direction of the ram.

The operation of the apparatus is as follows: A fire is first made at the bottom of the tube (*a*), and the gas burners (*e*) are lighted to heat up the tube externally. The material to be treated is then fed in through the hopper until the tube is full, and steam and air are admitted to the lower end of the tube by means of a pipe or pipes (*y*) as and when required. When the material is deemed to be sufficiently carbonized the ram is set in motion and continues travelling until the space between the ram and block is underneath the hole in the top of the box or casing, and the material falls down into this space. At about the same time the ram is reversed in its direction by contact with one of the triggers before mentioned,

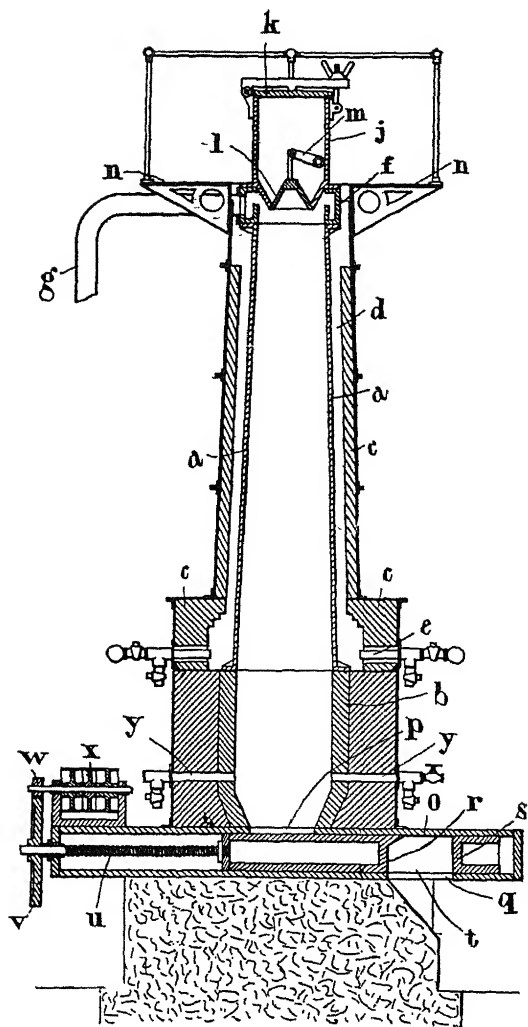


FIG. 24.—THE UNIVERSAL RETORT

and pushes the material forward to the end of the box, where it falls out through the opening (*q*) in the bottom of the box. The ram is again reversed, and the complete operation is repeated as long as desired.

As the material passes down the tube and is ejected by the ram, fresh material may be added through the hopper (*j*) to keep the tube filled, and so make the whole process a continuous one. The volatile products and fixed gases which are driven off from the material during its passage through the hot zone ascend to the top of the tube and are collected by the annular trunk (*f*) and conducted away by the pipe (*g*) connected therewith.

This retort works on the principle of the gas producer, only there is also external heating of the retort tube. This latter provision secures a long hot zone of even temperature, thereby accelerating the throughput. By using these two systems together, a wide range of temperatures and zone conditions can be obtained, which enables this retort to deal with almost any class of fuel.

One of the chief features of the retort is the ram for discharging the coke or residue. The ram has a reciprocating motion in a horizontal casing beneath the combustion chamber, and discharges the residue at intermittent intervals. By a simple adjustment which alters the rate of travel of the ram, the rate of discharge can be regulated to suit all classes of material.

This system has considerable advantages over the usual worm or valve method, as it allows the material to remain at rest while passing through the hot zone, which has been proved to be of importance in producing a good coke, and there is less liability to jamb or stick, which frequently happens with other systems.

The material to be treated is fed into the hopper and is passed into the retort tube by a lower valve. In the large units this valve is mechanically operated.

Steam and air are admitted into the combustion chamber by inlets, which are provided. By this means a slow, partial, or, if desired, complete combustion can be obtained. These inlets are at the bottom of the retort, and the hot gases so

produced cause the distillation of the coal in the upper regions of the retort. Naturally the external heating of the retort also assists. When smokeless fuel is desired, it is obviously not desirable to admit too much air and steam, because this, owing to partial decomposition, causes the fuel produced to be of a lower grade. It follows that if a coal contains a certain quantity of ash, that the ash in the final product will be increased if some of the carbon is burnt away. In any case, naturally, the extraction of the volatile matter raises the ash content. This, of course, is the case in all carbonization processes—either high or low.

The gases and volatile products are collected by the annular trunk at the top of the retort and conducted to the condensers and other auxiliary apparatus. A portion of the non-condensable scrubbed gas is returned to the retort and consumed at the external heating burners. Thus the retort is entirely self-supporting when once it has been started. By increasing the steam and air admission to the combustion chamber, larger quantities of gas can be produced as required. In fact, with using material of high ash content, which would produce a worthless coke residue, it may be found advisable to completely gasify it in the combustion chamber after the volatile matter has been removed in the upper part of the retort. In this case the residue will be simply ash and clinker. On the other hand, when using a fuel of high volatile and low ash content, it is, as already stated, desirable to reduce the steam and air admission to the lowest limits, thereby producing a smaller amount of gas but a yield of distillate, with a good smokeless coke residue.

Carter White System.

The late Dr. Carter White employed in Bombay for the distillation of coal a rotary retort of the cement kiln type. The heating was effected internally by inert gas and the irreducible gases from the operation.

The operation is started with gas producer gas at 400° C. to 500° C. of 140 B.Th.U.'s which circulates through the furnace until from 1,000 to 1,200 B.Th.U.'s is attained. The gases are then condensed by compression and stripped and reduced to

about 450 B.Th.U.'s, and re-heated to 500° C. These are passed through the retort again, gas producer gas being employed for re-heating. The producer is fired by a small quantity of the residues of distillation.

In addition to the systems described, many others have been introduced, but as the principles involved and the designs adopted are similar to, or are a variation of, those reviewed, it has not been thought necessary to expand the book to the extent demanded by the inclusion of these in detail. There are, for instance, the "Richards-Pringle," the Pritchard (American), the Fellner-Ziegler (German, horizontal), the Summers (American, horizontal), the Dvorkovitz (vertical), the Körting (vertical), on the same principle as the Universal, the McLellan, etc.

Distillation results of coal, shale, etc., by different systems will be found among the Appendices.

CHAPTER IX

SPECIAL POINTS IN LOW TEMPERATURE PRACTICE

THE various types of retorts have at present reached a degree of efficiency, which, if not absolutely perfect, give at least the satisfaction and security that commercial success can be achieved by their use. The stage of development at which low temperature practice has arrived provides a guarantee of results from which a profit can be realized in treating coal, oil shales, torbanite, etc. It is now indisputable that yields of from 28 to 32 gallons of crude oil can be secured from African coal containing 33 per cent of volatile matter, and a plant treating 100 tons daily is actually working and obtaining this excellent result. Oil shales, such as Esthonian, containing 36 per cent of volatile matter and yielding up to 90 gallons of oil per ton, can be treated by various retorts with a guarantee of a yield of 60 gallons per ton. Transvaal torbanite can also be treated, yielding up to 135 to 140 gallons of crude oil per ton, and even taking a mixture of coal and torbanite, as existing naturally in millions of tons, a yield of from 45 to 50 gallons per ton has already been obtained.

The now fully recognized principle and practice of using internal heat in retorts, through gases, inert gases, or preferably, superheated steam, has contributed considerably to the solution of the problem. Superheated steam, generated incidentally by the heating of the retorts, without the cumbersome equipment of boiler and superheater, is now employed, and has proved very successful. The various improved systems recently introduced are giving a substantial increase of the yield in oil and of much better quality, while at the same time, a marked decrease in the volume of irreducible gases evolved, occurs. The change in practice which has taken place in this direction is shown by the fact that only a year ago hardly one or two systems were using superheated steam, while at least half a dozen patents have been applied for, embodying this departure during the last six months.

Dr. J. B. Garbe strongly advocated this innovation at its inception.

The question of fuel also appears to be solved in the use of the spent shale or coke with a gas producer for heating purposes, the amount of coal or its equivalent used for this purpose per ton treated being not more than from 5 to 8 per cent of the tonnage treated.

The use of American retorts, based on the principle of the large roasting furnace, appears to be a move in the right direction, the only objection so far having been the high temperature employed, and the fact that it involves the production of too large a quantity of gas. If superheated steam, under economical conditions, as mentioned above is used, such retorts, although very expensive from the point of view of construction, may be the retorts of the future for low grade material.

The horizontal retort, with helicoidal screw propeller and superheated steam, appears, so far, the best for high grade material such as rich shales and torbanite. Its construction is simple and its efficiency considerable. The low temperature used, i.e. not exceeding 450° to 500° C., does not affect the working of the internal propelling screw, and the enhanced yield of oil obtained justifies the first cost of construction.

Another important aspect of the matter is that of condensation, and a great deal has been done in this direction. The use of steam internally in the retort enables a rapid evacuation of the oil vapours, and a more methodical condensation, while it assists considerably in the coalescence of the oil vapour elements. The practice of the rapid cooling of the vapours has been abandoned and the slow percolation of steam and oil vapours through appropriate screens or filters has secured a more efficient combination of the oil elements. This has naturally resulted in a higher yield of oil—an oil having a higher percentage of saturated hydrocarbons—and smaller quantities of irreducible gases.

It is a well-known fact that actual distillation occurs at a temperature rarely exceeding 350° C., and in rarer cases, at 400° C. The critical temperature of 412° C. is the temperature at which "cracking" begins, an effect which must, of course,

be avoided, and it has now been proved that with superheated steam, all the oil is produced below that temperature.

By-products Obtainable.

We cannot too strongly emphasize the point that at a low temperature, that is, not exceeding 450°C. , a higher yield of higher quality oil can be obtained than at temperatures which have hitherto been regarded as low. The term "low temperature" was adopted to express a state of carbonization at any temperatures which fell below those employed in coke ovens, not the temperatures between which the largest quantity of oil could be distilled. It was shown by Professor V. B. Lewes and others that, in connection with gas manufacture, a higher percentage of tar was secured at the lower temperatures employed, but even these from the oil production point of view were high, more especially when the character of the oil was considered. The modern problem, however, is not solved by quantity alone, it is essential that the oil distilled should be of the same character as that obtained in its natural state, and capable of providing the lighter fractions of the same series as from crude oil drawn from the well. The fact is not always borne in mind by those who design retorts and introduce new systems of what is termed low temperature carbonization, due to the fact that they do not keep in the forefront of their policy the production of oil of the highest quality, which is, for this country, the most essential by-product. With the majority of the known modern carbonization plants, it is possible to obtain ample supplies of high class smokeless fuel and large quantities of gas, results which can be secured by gas works of the modern coke oven. It is imperative, however, that we draw a very rigid line between old and new practice of coal carbonization.

On one side we have so-called low temperature processes employing temperatures of 500°C. and upwards. These produce a good solid residue, suitable as a domestic fuel, but the yield of oil is of secondary importance, and similar in quantity and character to that obtained by high temperature methods.

On the other side, we have a larger yield of oil and of a

paraffinoid character, identical with natural or well oil. The solid residue, however, is amorphous, porous and friable, but is eminently suitable for mixing with waste bituminous coal for the production of briquettes and ovoids. It is a product of this character we most urgently need to enable us to utilize the vast quantities of waste coal in this country, and to convert it into a high class fuel and to ensure the largest quantity of paraffinoid oils.

Oil must be made the main product of any low temperature process and the solid residue treated as a subordinate product. On this basis we serve the two chief needs of the country, namely, the provision of a home supply of oil of high grade and an amorphous residue which by mixing with waste bituminous coal, can be transformed into a high class domestic fuel and one entirely suitable for burning under boilers, either stationary, locomotive and marine.

It is in fact such a solid residue we require, so that the waste coal can be utilized for briquetting, and thus transforming into profitable material what is now merely lying above and below ground at the mines, unutilized.

The most important point in this question of distillation is that, hitherto, the oils obtained from coal were mostly of the aromatic or phenol and benzole series, and were not as valuable or as suitable for general purposes as natural oil and the oils derived from oil shales and torbanite.

The high temperatures employed in the past for the distillation of coal, and even 500°C . which till recently were deemed low temperature, caused secondary decomposition and the transformation of the oil.

The new system of distillation with, and by, the application of superheated steam, produces oils which retain their paraffinoid character and from which at least 25 per cent can be obtained as petrol.

In modern low temperature practice, the character of the oil distilled may be broadly stated to be as follows—

Hydrocarbons—approximately from 50 to 80 per cent consisting of—

(a) Paraffins from the lowest members of the series to members of the series, solid at normal temperatures ;

(b) Naphthalenes or aromatic hydrocarbons, occurring in the fractions above 60°C . and consisting of a large proportion of the distillate below 190°C . ; and

(c) Unsaturated hydrocarbons, olefine and cyclic, benzine toluene (their homologues are either absent or only present in small quantities, while naphthalene and anthracene are entirely absent), oxygenated bodies, from 20 to 25 per cent.

It must be remembered that the nature of the tar and oils depends on the description of material treated, as well as on the design of the retort, the temperature of distillation, the rate at which this temperature is attained, and the length of time during which the volatile products are exposed to that temperature. Low temperature, slow heating and rapid removal of the volatile products favour the formation of aliphatic or paraffinoid compounds.

CHAPTER X

MATERIALS AVAILABLE IN GREAT BRITAIN

THE materials suitable for low temperature treatment, and available in Great Britain, were inspected and classified during the war by a committee appointed by the Council of the Institution of Petroleum Technologists, and the results of the investigations showed that the sources from which oil can be obtained by distillation are—

1. Oil shales.
2. Coal.
3. Cannel coals and torbanites.
4. Blackband ironstones.
5. Lignite.
6. Peat.

On the basis of these various deposits—cannels and bastard cannels, torbanites and blackband ironstones—it was proposed to found a new industry in this country. The industry was to be simply the low temperature carbonization of the raw material, with the extraction of oil and all by-products that could be produced in sufficient quantity.

At a meeting of the members of the Institution of Petroleum Technologists, held on 19th February, 1918, there was appointed a committee known as "The Committee on the Production of Oil from Cannel Coal and Allied Minerals," with the following terms of reference—

"To obtain evidence in respect of the quantity of cannel coal and allied minerals available in Great Britain as a source of motor spirit, fuel oil, and other products, and to formulate a scheme for the utilization of such supplies."

The following extracts from the interim report of that committee, issued on 24th July, 1918, are of interest—

1. On our appointment by you at the end of February last

as a committee for the purposes specified in the Terms of Reference, we commenced our proceedings by appointing from our committee four sub-committees as follows—

(a) SUPPLIES OF MATERIAL

- (1) Quality of Material.
- (2) Quantity of material.
- (3) Grouping of collieries for assembling material with a minimum of transport.
- (4) Methods by which the maximum of retortable material can be obtained.

(b) TREATMENT OF MATERIAL

- (1) Retorting, forms of retorts, etc.
- (2) By-products, including residues.
- (3) Refining of oil.

(c) COSTS

- (1) Cost of raw material, including extra labour in mining and handling.
- (2) Cost of retorting plant, erection, and working.
- (3) Cost of refining oil.
- (4) By-products costs.

(d) FINANCIAL SCHEME

- (1) Wages.
- (2) Royalties.
- (3) Value of products.
- (4) Drafting of scheme.

2. The possibility of obtaining oil in quantity from the low temperature distillation of cannel-coal and its cognates has been considered from two other points of view, namely—

(1) As an immediate war measure, having in view the production of motor spirit and fuel for the Services, and

(2) As a permanent commercial undertaking and a measure of reconstruction.

3. Sufficient evidence having been obtained from colliery proprietors and others to justify the conclusion that a very large amount of retortable material can be obtained for the production of oil in Great Britain, the committee decided to issue this Interim Report.

4. The raw material in sight divides itself into three classes—

(a) Non-caking material with a high yield of oil giving a residue of low value as household and steam-raising fuel, but of considerable value for producer gas and other purposes.

(b) Caking and non-caking material with a smaller yield

of oil than (a) but affording a residue of great value for domestic and industrial fuel; and

(c) Material of a variety intermediate between (a) and (b).

5. As a result of tests carried out by various processes, it has been established that a yield of between 15 and 80 gallons of crude oil per ton can be obtained from material existing in the British Isles. This crude oil can be refined to give at least 8 per cent of spirit and 40 to 50 per cent of fuel oil.

6. The committee are satisfied that at least 10,000 tons per day of retortable material could be economically assembled for treatment, provided the necessary facilities were given by the Government and the requisite labour were available. At an average of 30 gallons of oil per ton, this would yield 300,000 gallons of crude oil a day, or upwards of 400,000 tons a year.

7. Much of this material has hitherto been mined but not raised, or if raised has been thrown upon the spoil heaps or returned to the underground workings. If the substitution of the shovel for the fork, so strongly demanded by the miners, were made obligatory by Government order, still more material would be sent up and wasted. If, however, the recommendations of this committee be adopted and retorts erected, the increased supply of material will be utilized and the colliery owner enabled to pay the miner for the extra tonnage brought to bank.

8. The development of the industry as a permanent commercial undertaking depends upon the utilization of the by-products and residues.

9. The efficient utilization by means of low temperature distillation of the heat energy of the raw materials employed will make available valuable constituents which now go to waste, and thus tend to relieve the shortage of fuel for domestic and industrial purposes.

10. (a) The residues obtained from caking materials will provide a considerable supply of clean fuel without smoke, and of high calorific value.

(b) The residues obtained from a non-caking material, high in ash, can be utilized in a producer for the production of power gas and sulphate ammonia. The quantity of gas must depend

on the relative proportions of carbon and ash in the residue, and consequently no generalization as to the yield of gas is possible.

(c) The residues obtained from a non-caking coal low in ash can be utilized in the manufacture of briquettes.

11. It must also be borne in mind that the utilization of the large quantities of residues obtainable from the treatment of non-caking material should greatly facilitate the schemes for the generation of cheap electrical power which have been the subject of consideration by the Electric Power Supply Committee of the Board of Trade and the Coal Conservation Sub-Committee of the Ministry of Reconstruction.

12. The technical advisers of the committee have carefully investigated several types of retort, and also have had submitted to them many suggestions by inventors and others which hold forth considerable promise. As the materials to be treated vary widely in natural characteristics and in their behaviour within the retort, it is apparent that no one type of retort can treat to the best advantage all classes of material. There is, however, every reason to believe that certain retorts which have been under consideration will treat either caking or non-caking bituminous mineral so as to give a satisfactory throughput. There are in existence retorts which will successfully recover the maximum oil content.

13. The committee have not overlooked the question of the labour which will be required, but they desire to emphasize the fact that the establishment of an industry for the low temperature distillation of cannel-coal and its cognates will afford many openings for the employment of unskilled surface labour.

14. The committee regard with apprehension the situation as to the supply of fuel oil and motor spirit and the long delay in taking action to develop home supplies.

A considerable number of tests have been carried out in different retortable minerals found in Great Britain in very large quantities, and a selection of the results obtained are given on page 124. These are perhaps of little practical value and are merely introduced to show the possibilities in this country of establishing a home supply of oil.

The great difference in the retorting value of these shales is shown, but the figures would be more valuable had the temperature at which they were treated and the place of origin been given.

SHALES

Water.	Fixed Carbon.	Ash.	Volatile.	Volatile in residue.	Crude Oil.	Sp. gr. of Oil.
%	%	%	%	%	Gall. per ton	
14·6	14·4	56·7	28·9	2·9	23·980	1·026
7·2	15·1	49·0	35·9	2·0	36·55	1·015
11·8	12·9	48·0	39·1	1·1	35·8	·996
6·4	16·8	47·0	36·2	2·8	34·37	1·005
2·1	9·0	75·0	16·0	2·1	16·7	·856
25·2	9·3	72·9	17·8	2·8	9·63	1·009
27·4	8·4	76·3	15·3	2·4	12·67	·995
1·9	38·5	25·5	36·0	3·6	40·97	·947
2·3	38·5	28·0	38·5	4·8	34·9	·946

The yields of oil from cannel-coal are more consistent in both quality and quantity and are among the most valuable materials in this country as a source of oil supply.

CANNELS

Water.	Fixed Carbon.	Ash.	Volatile.	Volatile in residue.	Crude Oil.	Sp. gr. of Oil.
%	%	%	%	%	Gall. per ton.	
1·6	48·8	31·6	21·6	0·9	22·53	·887
4·9	52·3	10·6	37·1	0·5	28·78	·953
2·2	39·1	31·7	29·2	1·5	27·39	1·094
8·8	63·8	3·5	32·7	1·4	33·64	·929
6·2	43·3	27·4	29·3	4·7	24·45	·963
2·4	41·0	19·11	39·9	0·7	47·87	·931
3·6	51·9	16·8	31·3	1·6	39·17	·927
6·5	25·0	49·9	25·1	7·7	25·21	·904
2·0	16·2	66·7	17·1	4·6	32·36	·896
4·2	61·7	6·7	31·6	3·3	29·0	·953
2·2	55·9	9·0	35·1	1·3	46·98	·939
3·5	33·4	31·7	34·9	2·0	42·35	·918
5·0	58·2	4·1	37·7	2·5	38·31	·947
11·1	55·1	11·2	33·7	3·0	33·53	·967
2·3	38·7	34·2	27·1	2·2	18·23	·947
2·7	41·2	37·6	21·2	2·0	20·53	·960
7·7	51·1	2·6	46·3	2·7	48·77	·946

Splint coal is found in the northern fields, chiefly in Northumberland and Durham, many thousands of tons of which are now won in the mining of coal and thrown away on to the

spoil heaps. This description of coal yields, under distillation, larger quantities of oil than ordinary bituminous coal as is evidenced in the figures given below—

COALS

Water.	Fixed Carbon.	Ash.	Volatile.	Volatile in residue.	Crude Oil.	Sp. gr. of Oil.
%	%	%	%	%	Gall. per ton.	
1·8	18·4	61·1	20·5	9·0	6·96	·949
2·5	22·5	47·7	29·8	7·5	19·42	·937
6·1	62·8	5·9	31·3	1·9	20·14	·995
6·6	41·7	20·4	37·9	4·7	41·41	·932

SPLINT COALS

Water.	Fixed Carbon.	Ash.	Volatile.	Volatile in residue.	Crude Oil.	Sp. gr. of Oil.
%	%	%	%	%	Gall. per ton.	
0·7	53·5	20·8	25·7	2·1	30·0	·959
0·3	55·8	18·6	25·6	1·8	40·0	·973
0·5	52·8	19·8	27·4	2·7	20·24	·990
0·5	52·3	20·2	27·5	2·6	30·67	·968

BATTS AND JACKS

Water.	Fixed Carbon.	Ash.	Volatile.	Volatile in residue.	Crude Oil.	Sp. gr. of Oil.
%	%	%	%	%	Gall. per ton.	
2·8	43·1	32·6	24·3	2·6	28·68	·938
2·6	49·0	17·4	33·6	3·6	41·68	·923
0·8	43·6	13·4	43·0	3·5	60·24	·918
2·9	44·2	26·2	29·6	3·8	31·82	·925
1·6	41·0	21·9	37·1	3·0	54·92	·915

The deposits of oil shales, lignite and peat are dealt with later, in separate chapters.

The figures showing the yield of oil from cannel-coal are confirmed by a later report of the Petroleum Research Department. This report is based on investigations made with the possibilities of producing oil in this country and dealt solely with this material and asserted that the average quantity of oil obtainable was 35 gallons per ton, no material yielding less than 25 gallons per ton. The report also stated that 98 batteries

of retorts, capable of dealing with 100 tons of material per day each, could be erected throughout the districts where cannel was available in quantity, providing an annual production of 98 million gallons of crude oil. From this it was stated five million gallons of motor spirit and from 60 to 65 million gallons of fuel oil, in addition to paraffin wax and sulphate of ammonia, could be produced.

CHAPTER XI

THE NATURE OF LIQUID FUEL OBTAINED FROM COAL

AN important investigation was made in 1922 into the nature of the various liquid fuels obtainable from coal by different methods by Mr. Harold Moore, M.Sc., A.I.C., and Mr. Arthur Grounds, B.Sc., A.I.C.¹ The high authority of the investigators and the fact that it traverses aspects of the subject in a manner not usually employed fully justifies its inclusion in this work.

In reviewing the nature and yield of the various liquid fuels produced by the carbonization of coal and the distillation of coal tar, remark the writers, it is of interest to consider the origin of the tar itself.

Coal tar is produced by the destructive carbonization of coal, and the constitution of the tar depends upon many factors, such as, for example, the nature of the raw material carbonized, the temperature of carbonization, the rate of increase of temperature in the charge, velocity of removal of the volatile products of carbonization from the heated space, and numerous other considerations.


Taking the first consideration into account, the tars obtained by the carbonization of lignites and brown coals vary very considerably in composition, and are generally of quite different constitution from the tars obtained by carbonizing the geologically older coals, such as the bituminous caking and non-caking coals, and the semi-bituminous coals sometimes used in gas-producer practice. The examination of lignite tars has formed the subject of special and very thorough researches by Fischer, Gluud, and Schrader, whilst Bone, in England, has also studied the treatment of lignite from the point of view of its better utilization by "up-grading," he having proved that a preliminary heat treatment will eliminate a large proportion of the water, together with a gas consisting

¹ *Oil Engineering and Finance*, Vol. I, p. 359.

for the most part of carbon dioxide. The resulting product of this process has a much higher calorific value than the crude lignite.

The temperature of carbonization also has a very marked influence on the composition of the tar produced, and, consequently, on the composition of the oils which are subsequently distilled from the tar. When coal is carbonized at low temperatures, such as 450° to 550° C., the tars contain a large proportion of bodies of the aliphatic or paraffin series, somewhat similar in chemical composition to the bodies contained in crude petroleum, whilst with increase in carbonizing temperature, these bodies are subjected to decomposition, polymerization and reaction with the residual coke before they can be removed from the highly-heated zone, with the subsequent formation of compounds of an entirely different nature—viz., aromatic bodies of the benzene series. The tar produced by high temperature carbonization has also a higher specific gravity than the low temperature tar prepared from the same coal, and it is also more viscous. High temperature tars generally contain a much higher percentage of free carbon than low temperature tars, owing to pyrogenic decomposition of the volatile products of carbonization by contact with the highly-heated surfaces of the walls of the retort or oven.

Composition of Coal Tars.

The composition of coal tar varies considerably with the type of plant in which the coal is carbonized, and with the method of carbonization adopted. We will first consider the tars produced in ordinary gasworks practice, as recovered from the hydraulic main and scrubbers. The retorts in use may be divided into three classes—viz., horizontal, inclined, and vertical. Horizontal retorts, of  section, were the first to be used, and the tar produced from coal carbonized in such retorts usually has a specific gravity of about 1.20. Owing to the difficulty of removing the gas and tar vapour quickly from the heated zone, the tar is brought in contact, for a considerable time, with the heated walls and crown of the retort, with the consequent production of an undue amount of free

carbon, of which such tars generally contain from 20 to 30 per cent.

Horizontal retort tars are rich in aromatic bodies, being at present the main source of benzene, toluene, anthracene, and naphthalene. The charge in a horizontal retort is subjected to very rapid heating, and this generally leads to a somewhat violent evolution of volatile matter from the coal, with partial combustion on the surface, and this is reflected in the fact that such tars contain more ash than the tars from inclined or vertical retorts.

The next step in the design of gasworks retort installations was the introduction of the inclined retort, and, as might be anticipated, the tars produced by these retorts are intermediate in composition and physical properties between horizontal and vertical retort tars. The latter tars are of much better quality than the horizontal retort tars, and are in great demand, particularly in Germany, from various installations of Dessau retorts, as fuel for Diesel engines. The coal, descending gradually into the body of the retort (in the case of continuous verticals), is subjected to a preliminary low temperature carbonization at the top of the retorts, and this is reflected in the analysis of the tar, which usually averages about 7 per cent hydrogen, indicating the presence of considerable quantities of aliphatic bodies. The tars are almost mobile and of low specific gravity, and contain very much less free carbon and ash than the tars from horizontal retorts. Most of the modern works are gradually installing vertical retorts, whilst the majority of new plants comprise vertical retorts only. The specific gravity of the tar ranges generally from 1.05 to 1.10.

Lignite tars are very much lighter than coal tars, the specific gravity usually lying between 0.88 and 1.08. This tar generally contains a certain amount of paraffin wax, and is consequently frequently semi-solid at normal temperatures. It oxidises very rapidly, since it is rich in unsaturated compounds, and on distillation the tar yields motor spirit, illuminating and lubricating oils, and paraffin wax. Paraffin bodies are present in large proportion, as are also benzene and naphthalene.

Moore (*Liquid Fuels for Internal Combustion Engines*, 1920,

page 96) gives the following figures for the composition of tar from various types of retort—

DESCRIPTION.	Sp. Gr. at 15°C.	Water.	Ultimate Com- position.		O. & N.	S.	Ash.	Coke.	Net Calorific Value.	B.Th.U's	Free Car- bon.
			C.	H.					Cals.		%
Low tem. carboniza- tion tar.	1.058	3.00	85.8	8.1	5.49	0.09	0.11	8.2	8,776	15,797	2.2
Horizontal retort tar.	1.180	1.75	91.5	5.2	2.60	0.50	0.20	24.0	8,645	15,561	18.2
Inclined retort tar	1.157	1.11	89.9	6.0	3.60	0.50	0.02	18.5	8,671	15,626	14.0
Vertical retort tar	1.089	2.25	88.0	6.8	3.80	0.60	0.03	6.1	8,664	15,613	1.7
Oil from low tempera- ture tar	0.884	Nil	85.6	11.4	2.48	0.40	Nil	0.84	9,558	17,204	Nil
Horizontal retort tar oil	1.065	1.00	90.1	6.8	2.40	0.50	0.20	3.0	9,243	16,637	Nil

Tars Derived from Coke Oven Plants.

These tars cover a very wide range, and may be similar in composition to either horizontal or vertical retort tars, according to the type of plant in which the coal has been carbonized. The design of the oven has a very marked influence on the physical properties of the tars. In general, chamber oven tars correspond more or less to the tars from vertical retorts, and these have been found to be suitable for use in Diesel engines. No general rules can be given connecting the specific gravity of the tar produced with the type of the oven adopted, as the tar varies enormously in composition even from retorts of identical construction, and small alterations in the structure seem to have an undue effect in modifying the composition and properties of the tar. The following figures are given by Moore (*loc. cit.*)—

DESCRIPTION.	Sp. Gr. at 15°C.	Water.	Ultimate Com- position.		O & N.	S.	Ash.	Coke.	Net Calorific Value.	B.Th.U's	Free Car- bon.
			C.	H.					Cals.		%
Otto Hilgenstock coke oven tar	1.208	6.00	90.0	5.4	3.8	0.8	0.02	26.8	8,624	15,523	23.0
Simon Carves coke oven tar	1.000	0.50	88.1	5.6	6.1	0.2	0.07	6.0	9,261	16,670	traces
Chamber oven tar	1.082	1.29	88.2	6.9	4.6	0.3	trace.	7.3	8,727	15,727	3.3
Blast furnace tar.	1.172	3.00	89.5	5.8	0.5	0.8	0.4	23.4	8,288	14,018	0.5
Blast furnace tar oil.	0.974	Nil	87.3	9.8	2.6	0.4	Nil	1.05	9,243	16,637	Nil

Included in the above table will be seen the analysis of a blast furnace tar and the oil derived from it by distillation.

The great drawback to the use of blast furnace tar is the uncertainty of its composition. The ash is liable to be very high, owing to the inefficiency of the dust-catching arrangements. In some of the blast furnaces in Scotland, where the price of coke is too high to allow of its economical use, raw bituminous coal is used in the blast furnaces, and as the charge slowly sinks into the heated zone, the coal is subjected to a slow heating, and as there is a way of escape open, viz., through the throat of the furnace, the volatile matter evolved is very similar in composition to that from a low temperature carbonization process, and the tar contains a considerable amount of paraffinic constituents, which have a pronounced effect on the uses to which it can be put. If the dust-catching arrangements are at all faulty the ash passes into the tar, and on distillation is concentrated in the resulting pitch. Blast furnace pitch is on this account of very little use for the purpose of agglomerating small coal for briquette manufacture. The ash is a drawback from the point of view of competing with large, clean coal, and also, since it exists in a very fine state of division, it breaks down the agglutinating power of the pitch. In the case of a coal, it has been shown (Grounds and Sinnatt, J.S.C.I., 1920, 39, 83-85T) that if an equal weight of inert matter, such as gas carbon, screened through a 200-mesh sieve, be added to a coking coal, it will entirely destroy its caking properties, and there is no doubt that the fine ash in blast furnace pitch acts in a similar manner. The pitch is dull in appearance, and, unlike a good gasworks or coke-oven pitch, will not pull out into long threads when softened, but breaks off short and cracks on the surface. On this account, too, the tar is of no use for combustion engines, and one of us has examined a tar containing as high a percentage of ash as 13.5 per cent. The oil, however, is suitable for this purpose, as it is rich in aliphatic bodies and is of low gravity. The production of blast furnace tar is not very great, and only amounted to 140,000 tons in the year 1917, since which date no reliable figures have been available. Gas-producer tars vary considerably in composition, according to the type of producer in which the coal has been gasified. The tars are liable to be uncertain in composition from time to time,

even from the same plant, and their use as engine fuels is generally prevented by the high quantity of ash and moisture which they contain. The water is introduced by the steaming of the coal in the producer, and it is very troublesome to separate. The production of producer gas tar in 1917 was 51,000 tons.

Carburetted Water Gas.

In the manufacture of carburetted water gas, oil gas is frequently used to enrich the ordinary water gas. The oil gas is produced by cracking gas oil, a residue being obtained which consists of unchanged oil, mixed with a large proportion of aromatic hydrocarbons produced by the cracking of the oil. Other products from the water-gas section become mixed with the residue, and the result is a light, mobile, reddish-brown liquid, having a specific gravity of about 1.05, which liquid is an excellent fuel if dehydrated, providing that the ash content be kept low.

The tar is very liable to contain an undue proportion of moisture, as in the case of producer gas tar, and the actual amount of water present depends very largely on the programme of operation. These emulsions are often very difficult to separate, but a suitable tar provides an excellent fuel and commands a good price. The average composition of carburetted water gas tar is as follows—

Specific gravity	. . . . .	1.020
Flash point (closed test)	. . . . .	175° F.
Carbon content	. . . . .	91%
Hydrogen	. . . . .	7%
Oxygen and Nitrogen content	. . . . .	1%
Sulphur content	. . . . .	1%
Ash	. . . . .	0.0-0.50%
Coke value (about)	. . . . .	8%
Free carbon content, less than	. . . . .	3%
Calorific value (net)	. . . . .	9,111 calories/kg. 16,400 B.Th.U. lb.
Percentage distilled at 350° C.	. . . . .	60 %

This tar is very seldom distilled separately from the gas tars, but is generally mixed with such tars at the gasworks. When distilled separately, however, it gives a high yield of creosote, in the region of 60 per cent. The oil is mobile, light yellow in colour, clear and free from naphthalene, and has a calorific value of 9,277 calories/kg., or 16,700 B.Th.U./lb.

Two methods are adopted of controlling the distillation of the tar in this country, one method being to work to a certain specific gravity of the distillate, and the other to work to definite temperatures, when the "change over" is made. The following temperatures are usually adopted—

	Temperature of distillation.	Specific gravity (Approximate).	Yield.
First runnings or crude naphtha	Up to 110° C.	0.920	0%
Light oil	110°-200° C.	0.995	3.1
Crude carbolic oil	200°-240° C.	1.015	1.7
Creosote oil	240°-270° C.	1.050	3.5
Anthracene or heavy oil . .	270° to finish	1.095	12.0
Residue	Varies		9.7
			66 (approx.)

The finishing point is determined by the quality of pitch it is desired to make. Formerly, much soft pitch was made, leaving in the whole of the anthracene oil; but this is not now done, and if a soft pitch is desired, the pitch is usually taken to the medium hard, or hard state, and is then softened in the still by the addition of some of the lighter oils.

The main use of pitch is as a binder in the manufacture of patent fuel, although considerable quantities are used for the manufacture of roofing felts, for road-making, for the manufacture of electrical insulators, and numerous other purposes. For patent fuel, the pitch is taken to the medium soft stage, and has a twisting point of 52° to 58° C., the melting point being about 88 to 100° C. For fuel oil purposes, the creosote oil and anthracene oil are frequently mixed and sold under the name of tar oil. The crude naphtha, light oil, and carbolic oil are washed with caustic soda and sulphuric acid for the separation of tar acids and the bases such as pyridene. From horizontal retort tars, the yield of tar oil may be taken at 28 per cent, whilst from coke-oven tar this figure is usually about 32 per cent, the pitch yield being about 65 per cent from horizontal retort tars and 60 per cent from coke-oven tars. Good quality vertical retort tars generally yield about 45 per cent of tar oils, and give 45 per cent of pitch. Carburetted water gas tars give, on distillation, about 60 per cent of carburetted water gas tar creosote.

COAL TAR CREOSOTES

	Average.	Maximum.	Minimum.
Specific gravity	1.017	1.090	0.950
Water	1.08%	12.00%	None
Carbon	89.2%	90.0%	87.1%
Hydrogen	7.3%	8.0%	6.5%
Oxygen and Nitrogen	3.9%	4.8%	3.0%
Sulphur	0.636%	1.02%	0.28%
Ash	0.005%	0.10%	None
Closed Flash Point, °F.	164	208	97
Viscosity in Redwood Units at 70°F.	8.6	23	6.8
Calorific Value, Gross B.Th.U.	17,365	17,946	16,400
Net B.Th.U.	16,597	17,174	15,903

ENGLER DISTILLATION

	Average.	Maximum.	Minimum.
At 250° C.	58%	76%	28%
At 300° C.	79.5%	94%	51%
Coke yield	3.3%	14.7%	1.3 %
Free Carbon	0.26%	5.2%	None
Tar Acids	9.5%	30.0%	Trace
Temperature of Spontaneous Ignition (In oxygen, °C.)	480	520	415

The process adopted varies, but generally the first runnings give crude benzol and crude toluol, the remainder going to the solvent naphtha fraction. The latter fraction is derived mainly from the light oil, the residue from which goes to the creosote, whilst the crude carbolic oil is washed free of phenol and tar acids, naphthalene is separated, and the oil goes either to the creosote or is sold specially. Disinfectants are prepared from this particular fraction.

Coal Tars as Diesel Engine Fuels.

As is pointed out also by Moore,¹ the burning of coal tars in internal combustion engines has been advocated for many years by experts, but little development in this direction has taken place. At the present time there does not appear to be much chance of Diesel and semi-Diesel engines being adapted to the burning of raw coal tars, in spite of the comparative cheapness of the fuel; the reason being that it is generally necessary to decrease the rating of engines used for

¹ *Oil Engineering and Finance*, Vol. I, p. 57.

this purpose, which means a higher capital charge on the installation.

Coal tar creosote came into use on Diesel and high-compression semi-Diesel engines during the war as a result of the high price of petroleum products, but at the present time creosote is dearer than imported fuel oil, and its use has almost ceased. With the improved processes referred to in this work, there does not appear to be any reason why the prices of the home-produced Diesel oil, provided it is distilled in sufficient quantities, should not be so reduced as to make it attractive to Diesel engine users in this country.

Whereas normal coal tars and normal coal-tar creosotes possess high spontaneous ignition points, causing ignition difficulties when these fuels are used on Diesel engines, the low temperature tars, though higher in ignition point than the pure petroleum products, are much more satisfactory in this respect than the products of the high-temperature carbonization of coal. In addition, their low viscosity and comparative freedom from solid particles, such as free carbon, make the raw tars produced from low temperature carbonization plants more satisfactory fuels than the high temperature tar, apart from the ignition problem. In fact, it is well known that Diesel engines in Germany have been running for many years on vertical retort tars produced in Dessau retorts. The tars produced in this particular plant are more akin to low temperature products than to normal coal tar. Should the low temperature carbonization process be developed on such a scale as to yield a really commercially important quantity of tar, it would probably be found most economical to utilize the raw tars as Diesel engine fuels, without submitting them to further distillation. In the past, low temperature tars have been notorious for the quantity of water in them, which was held up in the form of an emulsion. In many cases the tars, on leaving the plant, contained over 50 per cent of water, and the removal of this water presented the greatest difficulty. It is, however, claimed in some of the modern low-temperature processes that water-free tar is generated directly from the plant.

If such tars can be marketed at a price to compete favourably

with petroleum oils, there is no doubt that they would receive most serious attention from Diesel engine users, and probably they would be found to be a most satisfactory fuel for the high-compression type of semi-Diesel engine. The high compression engines, such as Crossley, Ruston, and Campbell engines, possess the property of utilizing heavy oils to a remarkable extent, being known to give satisfactory working on Mexican furnace oil, so they should have little difficulty in burning raw low-temperature tars. At the moment there is little of this tar available, but the proposition is particularly tempting, as its development would open a source of fuel oil actually produced in this country.

CHAPTER XII

TREATING THE RESIDUE FROM DISTILLATION

THE treatment of coal by low temperature distillation cannot be dissociated from the use of the solid residue obtained as a result of this distillation, for in Great Britain, at least, the two aspects of the matter are inseparable. The relinquishment of the present methods of burning coal in its natural state, and the general adoption of a smokeless, but greater heat-giving fuel, must go hand in hand with any progress of low temperature distillation. At the present time, prejudice against a domestic fuel which does not emit smoke and flame prevails among all consumers, and these must be educated to the fact that by using a fuel which does not provide these picturesque emanations, they will obtain a greater amount of heat per ton, which expressed in sterling, will represent a considerable saving in housekeeping.

For ordinary industrial fuel, steam boilers, locomotives, etc., bituminous coal should be passed through low temperature retorts, extracting the maximum quantity of oil of the highest quality, and a synthetic coal formed of the residue obtained. This should be prepared in such a manner so as to be suitable for the different purposes required, as is effected so efficiently in Belgium. The great mistake which has been made by the majority of those who have turned their attention to the invention of a process whereby the by-products from coal could be obtained has been that they have set out with the idea of securing as great a variety of products from the coal as possible, instead of directing their energies into one definite line. It is impossible to secure a large quantity of oil and at the same time produce satisfactory quantities of good residual fuel and gas. The object which should be kept right in the forefront is that of producing the largest quantity of oil, and using whatever residual fuel is obtained for briquette manufacture, combining this with waste coal, of which such vast

quantities are available. This question of briquetting has in Belgium become a fine art, all waste and rubbish being crushed, washed, concentrated and mixed with inferior coal and transformed into briquettes at a very nominal cost in well-devised plants working automatically and with a labour outlay of less than one shilling per ton. The chief expense incurred is in respect of the binder, which up till recently has been confined to pitch produced from coal tar. For some time now, however, this pitch has stood at a prohibitive price, and efforts are being made to adopt a pitch produced from heavy petroleum; but if this low temperature carbonization business is carried out efficiently there should be no need to resort to imported mineral for a binder. From coal treated by the low temperature process, the oil is extracted in as large a proportion as possible, and the friable coke obtained turned into briquettes as suggested above, while the pitch resulting from this process can be used as the necessary binder. Moreover, an ideal fuel would be produced of a higher calorific power than the original coal treated. It is merely a matter of arithmetical calculation to ascertain what the value of such a procedure would be.

Low temperature carbonization with superheated steam will extract oils and preserve their paraffinoid quality, avoiding the production of aromatic and acid products. The matter of briquetting is such a commonplace affair abroad that no one who has not inspected the developments in Belgium, France, and Germany can realize the backwardness of England in this direction, and it is evident that this is due not only to conservatism in the matter, but to the fact that this country possesses such potential supplies of coal which have shown no signs yet of becoming exhausted, and that, therefore, they can be dissipated carelessly. The position of things is quite different in Belgium, where the output of coal amounts to only 20 to 25 million tons a year, and whose people are therefore compelled to exercise economical methods, or pay high prices for the imported mineral. From the inferior coal and slag produced, the Belgians manufactured in 1921 no less than three million tons of fuel in the form of briquettes. This quantity represents 12 per cent of the total produced, while

England, with a production of over 250 million tons, manufactures only two million tons of briquettes, or less than 1 per cent of the total quantity produced. Even, therefore, compared with such a small country as Belgium, we are, from the scientific standpoint, infinitely less advanced in this matter of the proper utilization of coal.

Brown coal and lignite can also be treated in the same manner for oil extraction and briquetting, and this has been done in Germany, France, and Russia for a considerable time, while it has also been recently introduced into America with considerable success. Coal briquetting is an essentially Belgian industry, initiated as far back as 1828, but it was not until 1858 that its advantages were fully recognized, and developments on a large scale occurred. After the opening of the Rhur coalfields the Germans were quick to recognize the advantages of coal briquetting, and started production on a large scale, not only on ordinary coal, but also with brown coal or lignite.

Many disappointments have been experienced, chiefly due to lack of experience and practical knowledge. Briquettes were manufactured from best waste Welsh coal, but could not be used in locomotives and under marine boilers, as being far too rich in hydrocarbons. The blending of various qualities of coal has, however, reached in Belgium almost perfection, and the briquettes made are practically smokeless, and of a very high calorific power.

The universal adoption of briquetting inferior coal, washed dust, lignite, etc., has rendered, at least on the Continent, this industry a natural adjunct to every colliery of importance, and such briquetting is being done at a merely nominal cost. It is undoubtedly through this that the practicability and commercial success of oil extraction from coal will emerge. It is now proved that about 1 gallon to $1\frac{1}{4}$ gallons of oil can be obtained for each 1 per cent of volatile matter contained in the coal. The oil extracted will have an amorphous residue which, ground and blended roughly in proper proportions and treated by a modern process, as universally used on the Continent, may be transformed into briquettes of any form and size as most suitable for industrial or domestic use. Such

briquettes, being synthetically constituted, without any superfluous bituminous element, will be smokeless, and thus will be solved the critical question of the prevention of smoke, fog, etc., besides enriching the nation with many thousands of tons of oil actually burned on the altar of convention and prejudice. It is a fact that to-day in far-away India, at Bombay, there is already working a small plant treating 100 tons a day of coal imported from Natal in South Africa. The coal contains 32 to 33 per cent of volatile matter and yields over 34 gallons of oil, of which more than 45 per cent is directly transformed into motor spirit, lubricating oil, and fuel oil. The solid residue, after distillation, is transformed into briquettes for domestic purposes, the natives being eager to buy these "coal balls," which are smokeless and which they burn in their native fire-boxes. The system used is internal heating at very low temperatures.

American Practice.

In America the value of briquetting bituminous coal is fully recognized, and is making good progress. Among the processes employed is that being worked by the International Coal Products Corporation of New York, producing a high-grade smokeless fuel, to which the name "Carbocoal" is given. This fuel is successfully used in locomotives for industrial steam raising, as well as for domestic purposes. The essential features in the process for production of carbocoal is an initial continuous low temperature distillation of the raw fuel, which may be lignite, coking, semi-coking, or non-coking coal of a high volatile content. After being crushed to pass a $\frac{1}{4}$ -in. mesh, it is fed to the primary retort, maintained at 850-900° F. A twin set of paddles inside the retort serves the double purpose of advancing the charge, and at the same time keeping it well agitated so that all portions are fully exposed to the heating of the retort walls. Two to three hours are occupied by this primary distillation process, which reduced the volatile content to about 8 per cent. The result is a very large yield of tar and gas, leaving a residue rich in carbon, which is called semi-carbocoal.

Upon discharge from the retort, this residue is ground up

and thoroughly mixed with pitch binder obtained from the first distillation process, and the mixture is formed into oval briquettes by passing between roll dies. These briquettes are then fed by gravity into a secondary inclined retort, where they are subjected to a high temperature distillation (at 1,800° F.) for a period of five or six hours.

During this second distillation process, the pitch is completely coked, and the briquettes shrink a little in size. Upon discharge from the second retort, the briquettes are quenched and then stored ready for shipment.

These briquettes are available in five sizes, ranging from 1 oz. to 5 oz., the larger adapted to locomotive and the smaller to domestic use.

Tests on this synthetic fuel have showed its ability to evaporate from 8.5 lbs. of water at a combustion rate of 100 lbs. per square foot of grate surface per hour to 12.8 lbs. of water at a combustion rate of 27 lbs. per square foot of grate surface per hour, from and at 212° F., per pound of fuel fired; and that it requires no greater draft than bituminous coal. A maximum combustion rate of 166 lbs. per square foot of grate surface per hour has been reached for short periods with this fuel.

At the Clinchfield (Va.) plant of the company, operated by the Clinchfield Carbocoal Corporation, about 600 tons of coal per day are put through this process, yielding the following approximate quantities of carbocoal and by-products—

Carbocoal	420 tons
Tar	16,200 galls.
Gas	5,400,000 cu. ft.
Concentrated Ammonia	1,300 galls.
Tar Oils	8,100 „
Motor Spirits	1,200 „

The method of submitting ovoids after production to a process of distillation is not new; and apart from the above-mentioned fuel, "carbocoal," another American concern manufactures this form of fuel in a similar manner and gives it the name of "carbonets." In Belgium also ovoids are subjected to what is known as "sweating" and are marketed with a maximum of 7 per cent of volatile matter. These are disposed of chiefly in Paris for old-fashioned central heating plants.

The practice has now been adopted in England, the object of which is to relieve the fuel of the bulk of the hydrocarbons and to secure greater cohesion in the ovoid, making it less porous and brittle. This double handling and treatment of the fuel increases to some extent the cost of production, though a small saving is effected on pitch, which is not necessary under these conditions as a binder.

It should be pointed out that such a method is not applicable to briquettes of large size, say from 10 to 20 lbs. in weight. Their shape and dimensions make them quite unsuitable for treatment with a low temperature, as the penetration of the heat, to which they would, in these circumstances, be submitted, would not be sufficient to distil off the volatile matter in the interior of the briquette. To effect this high temperatures would be necessary and this would add considerably to the cost of production.

Recent practice, which has been directed towards manufacturing briquettes and ovoids by heating coal to coking point and subjecting this to pressure only and without binder, is merely reverting to the old and primitive methods of the 1830's and 1840's, which was abandoned owing to the cost and technical difficulties involved.

CHAPTER XIII

COAL AGGLOMERATE

WE have, in previous chapters emphasized the point that the establishment of an oil industry in this country is indissolubly bound up with the commercial utilization of the solid residue obtained from the distillation of coal and the provision of a fuel equal in calorific power to that of coal. It has also been stated that the only process by which this can be carried out is by treating the enormous masses of waste coal and the solid residue referred to, and transforming these into coal agglomerate or briquettes.

There is an erroneous impression extant that in encouraging the use of this form of fuel the production of coal would be affected. That this is untrue in fact is proved by the instance of Belgium, where the extension of the use of briquettes has led to an increased output. This form of fuel is, in this country, wrongly termed "patent fuel." There is really no patent connected with it as its manufacture is public property throughout the world.

Briquette is the name given to an agglomeration of small coal united with a binding material, and ovoid is the name given to the same, made about the size of an egg. It is rather remarkable to turn to a little country like Belgium to find the most prominent instance of the rational treatment of coal. Here and in France the coal briquetting industry originated and was developed.

This industry is not, as many appear to think, by any means a new departure. Records show that the Chinese, centuries ago, were using compressed coal formed into balls. In England, in the year 1603, Hugh Platt described in a pamphlet a new compressed fuel manufactured in the year 1594, which was composed of coal dust, saw dust, and oak tan bark with cow-dung as a binding material.

Nelson Boyd, at a later date mentions the manufacture of

coal balls, taking his idea from Liege in Belgium, and Aix-la-Chapelle, where coal balls were made by mixing coal dust and loam or clay together. This practice is still common among the peasants of Belgium. Fuel of this description is economical and smoulders away, producing no flame and little smoke although the ash is considerable. The same authority gives also a lengthy description of a similar fuel made with straw and tan as a binder, used for reducing the ash.

In 1776 and 1813 there are further records of balls and eggs being made from coal dust with from 10 to 15 per cent of loam or clay in the neighbourhood of Luttitch (Liege) for use as a domestic fuel. In the early days in Belgium these coal balls were called "Liege."

Later on, the coal briquettes were manufactured in blocks of between 2 and 3 sections, containing from 8 to 10 per cent of plastic clay.

In the year 1818 there are records of such briquettes being made by machinery in Belgium, and a serious development was recorded in that country and France. Between 1832 and 1842 a great impetus was given to the briquette industry by the application of coal tar pitch as a binder. This was introduced by an Englishman, a Mr. William Wylam, of Newcastle-on-Tyne, and such binder is at the present time still employed. Quite recently attention has been directed to the heavy residue from well oil distillation.

Hundreds of patents have been taken out in this country, and tried, and are still being tried with the object of replacing coal tar pitch as a binder, but nothing of a permanent commercial character has so far been recognized as practicable.

Briquettes and ovoids, to be satisfactory and efficient, should be homogeneous, sonorous, and smokeless as possible. Breakage in transport must not exceed 5 per cent. The average specific gravity should be about 1.5.

They must not be hygroscopic; the moisture contained not exceeding 5 per cent, the amount of ash not above 10 per cent, although for ovoids for domestic purposes there is no objection to the per cent of ash reaching 15.

They must be easy to kindle, burn with a lively, practically smokeless glow, and must not fall in pieces in the fire.

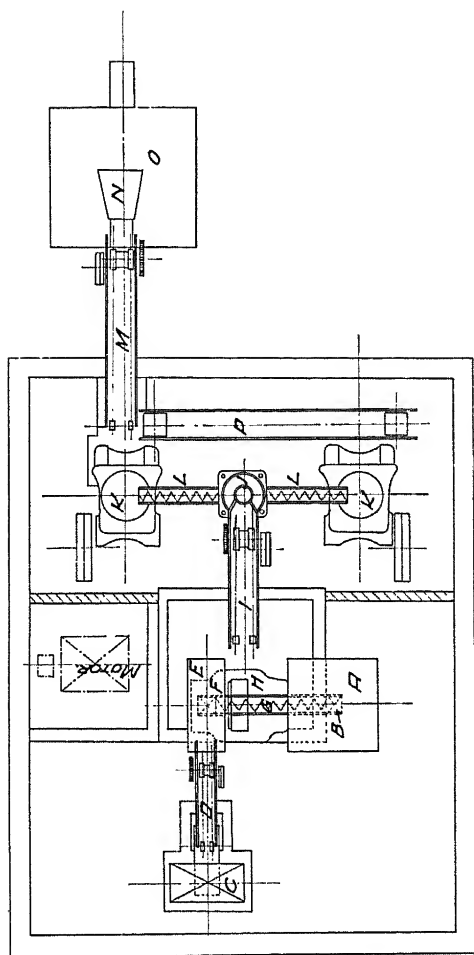


FIG. 25.—PLAN OF PLANT FOR PRODUCING OVOIDS

- (A) Coal bin, crusher to bin. (B) Coal feed measure. (C) Pitch consumer. (D) Bucket chain elevator, to lift pitch from distributors. (E) Pitch bin. (F) Pitch feed measure. (G) Spiral conveyor. (H) Carr crusher. (I) Bucket chain elevator, to lift from mixer to kneader. (J) Kneader and superheater. (K) Ovoid press and distributors. (L) Spiral conveyor. (M) Bucket chain elevator to carry ovoids to storage bin. (N) Tremmel. (O) Storage bin. (P) Belt conveyor.

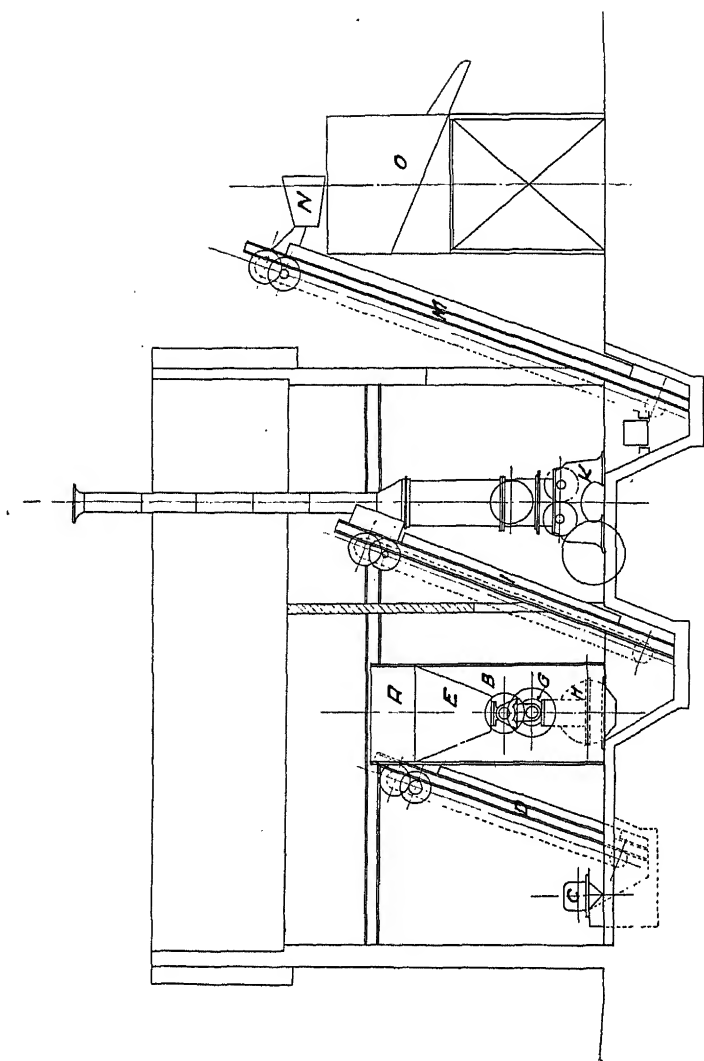


FIG. 26.—SECTIONAL ELEVATION OF PLANT FOR PRODUCING OVOIDS

Their steaming power must be approximately equal to that of good steam coal.

One of the great mistakes made since the initiation of the briquette industry in this country has been that of using the best coal for briquette making. These have had a far too high percentage of volatile matter and consequently produced disastrous results when burnt in locomotives and marine boilers, by choking the boiler tubes. Briquettes or ovoids for domestic purposes should contain from 7 to 15 per cent of volatile matter and from 10 to 15 per cent of ash.

For railway and marine work these items should be—Volatile matter, 10 to 16 per cent, and ash, 6 to 10 per cent.

Briquettes for special purposes should be made to suit the requirements, as in Belgium, and as indicated by the list given subsequently.

Briquettes and ovoids are made to order for any specific purpose, considering the blending of the coal and determination of the nature of the fuel the briquette has to displace.

They are, in reality, a synthetic coal: anthracite, anthracitic coal, coke, semi-coke, peat, lignite; indeed, anything that can be treated by low temperature carbonization. They can be converted into briquettes, and in all cases by intelligent blending are made into high class valuable fuel and adapted to every purpose.

The method of treatment and the machinery and appliances used in Belgium are the results of constant improvement during the last 60 years. One firm alone has erected works producing now over 1,200 tons per hour or more than 3½ million tons per annum, and are still extending their plant.

In order to give a clear idea of the extent of this work in Belgium, we cannot do better than append a synopsis of their practice.

There are no patents in use, but the essential part of their success lies in the perfect adaptation of every detail to the purpose in view (Figs. 25-29). All the work is automatic and the labour required for an output of a recently completed works, dealing with 100 tons per hour, is only about 30 men, including foreman, engineer, and the necessary unskilled labour. The cost of this labour does not exceed 1s. per ton.

FUELS PRODUCED IN BELGIUM AND THE NUMBER OF PRODUCERS OF DIFFERENT DESCRIPTIONS OF FUEL

COAL—MEDIUM BITUMINOUS

Volatile matter = 14-17 per cent.

Raw Coal and Washed Coal.

Uses.—Domestic purposes; steam coal; coal briquettes, and ovoids.

Size of Products.—Lumps, cobbles, nuts, pea-nuts, washed pea-nuts, fines, and dust.

Ash.—Classified and washed, 6-8 per cent; washed, 10-12 per cent; raw, 15-20 per cent.

Producers.—Centre, 19; Liege, 24; Mons, 8.

COAL—QUARTER BITUMINOUS

Volatile Matter = 11-14 per cent.

Uses.—Domestic; coal, dust or washed; central heating; brick burning; lime kiln. Steam coal and briquettes and ovoids are used here. Slow and regular combustion are required.

Size of Products.—Same size as former.

Ash.—Classified, washed, 6-8 per cent; crushed, 5-7 per cent; washed, 10-12 per cent; raw, 15-20 per cent.

Producers.—Charleroi, 13; Liege, 8.

LEAN AND ANTHRACITIC COAL

Volatile matter = 6-10 per cent.

Coal, Raw, Washed, and Crushed.

Uses.—Slow combustion stoves; central heating; gas producers; brick burning; lime kilns; ore treatment. Used for very slow or regular combustion.

Ash.—Crushed and washed, 6-8 per cent; crushed, 5-7 per cent; washed, 10-12 per cent; raw, 15-20 per cent.

Producers.—Charleroi, 18; Liege, 12.

COAL—THREE-QUARTER BITUMINOUS

Volatile matter = 17-40 per cent.

Raw Coal and Washed Coal.

Uses.—Three-quarter domestic coke: smithy, rolling mill, sugar mill, steam generation. *Bituminous*: iron and steel works, glass works, potteries, etc. *Special rich to best Welsh*: gas works, coke ovens.

Producers.—La Campine (new coalfield), 1; Centre, 5; Charleroi, 3; Liege, 8; Mons, 13.

COKE

(Metallurgical; Foundry; Washed coal, etc.)

AGGLOMERATE COAL (OVOIDS)

(Lean Coal, Anthracite, Half Bituminous, Special Ovoids.)

Volatile matter = 8-16 per cent.

Ash.—40-50 grammes. Size and weight variable from 1½-2 oz.

Producers.—*Lean Ovoids*: Charleroi, 13; Liege, 5. *Special Ovoids*: Charleroi, 2; Liege, 3. *Ovoids, half bituminous*: Centre, 3; Charleroi, 7; Liege, 4; Mons, 2.

Briquettes.

Types 1 and 2, Belgian State. Marine.

Specifications of Belgian State Railway and Great French Company, weight and size to order from 12-22 lb.

Uses.—Locomotives, bunker, and industrial.

Producers.—Types 1 and 2, Centre, 4; Charleroi, 24; Liege, 18; Mons, 4. Marine (Admiralty), Centre, 3; Charleroi, 7; Liege, 2; Mons, 1.

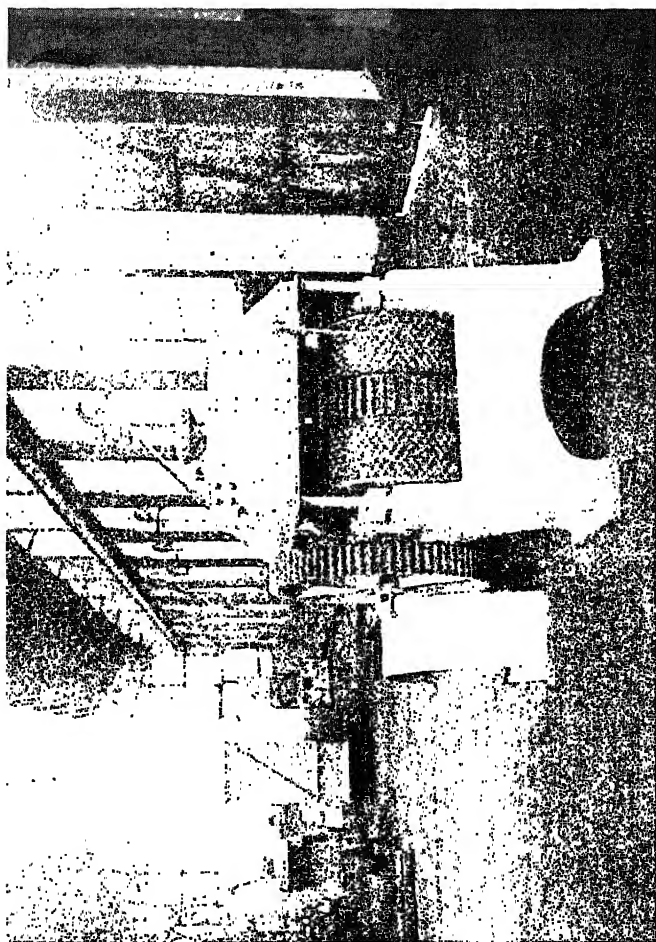


FIG. 27.--GENERAL VIEW OF OVOID PRESS

A Typical Belgian Briquetting and Ovoid Plant.

One of the most modern plants for briquetting coal and coal residue is that employed at the Charbonage du Carabinier a Pont du Loup, one of the largest coal mines near Charleroi. This plant, of a capacity of 100 tons per hour, embodies the latest improvements, not only as regards machinery, but as regards the completeness of the accessories and appliances for handling the coal, pitch, ovoids, and briquettes, and is absolutely automatic, from the tipping of the coal into the coal bins to the loading of the products into the railway trucks or canal barges. The plant is erected for 60 to 80 tons of briquettes per hour, according to sizes, the size varying from 10 lb. to 22 lb. per briquette, according to requirements, in addition to 20 tons of ovoids per hour, the unit weight of which is about $1\frac{1}{2}$ oz., or altogether from 80 to 100 tons of products per hour.

The ovoid press (Fig. 27) consists of a strong cast-iron frame in one piece, the bearings carrying the two shafts on which are keyed the cylinders with the ovoid moulds or shells fixed in such a way as to be easily removed and regulated by wedges and screws, so as to meet the wear and tear of the cylinders. The moulding of the ovoids is done in the shells (allveoles) scooped around the circumference of the cylinders, which revolve tangentially in opposite directions and at equal speed. The driving is done by pulleys (fast and loose) and a set of cast iron cog-wheels, machine cut. On the frame is fixed a mixer distributor in steel sheet and provided with a proper stirrer, driven by bevel gear. The purpose of such a stirrer is to keep the paste fluid and to distribute it regularly to the moulding cylinders. The weight of such a press for a capacity of 10 tons per hour is 15 tons.

The briquetting presses employed are of the open mould type (Fig. 30), and of the two million tons of briquettes now manufactured yearly in Belgium over 90 per cent are made by such presses. These presses are capable of using washed coal without drying, and will agglomerate coal with as much as 10 per cent of moisture without inconvenience. The press is highly efficient and of large output, namely from 12 to 15 tons per hour. The construction is of the greatest simplicity and

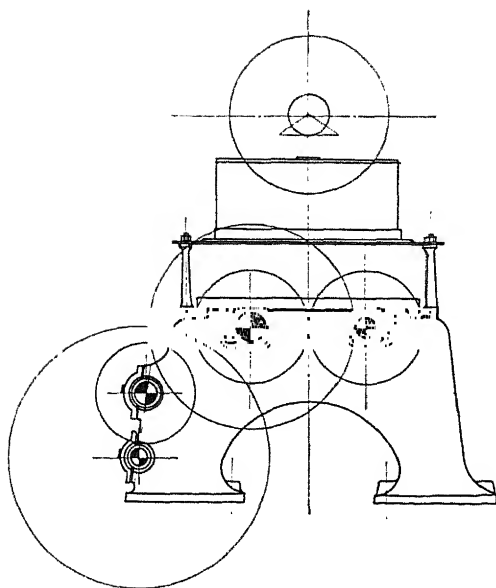


FIG. 28.—SIDE ELEVATION OF OVOID PRESS

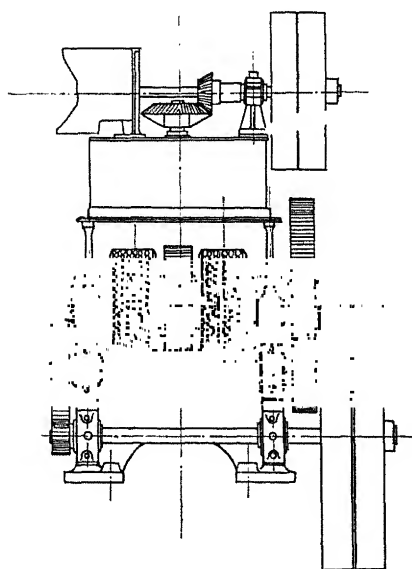


FIG. 29.—FRONT VIEW OF OVOID PRESS

strength, and easy to work, while the upkeep is almost nil. In addition, all the parts are made to bear the greatest resistance and shock. If anything should occur, the belt on the

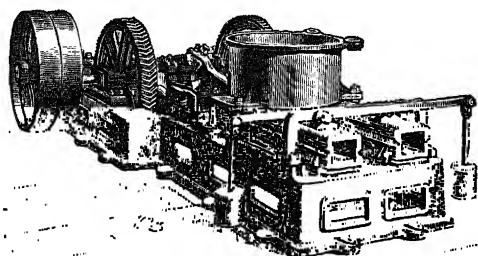


FIG. 30.—OPEN MOULD BRIQUETTE PRESS

main pulley would slip and the press would stop instantaneously. The ordinary compression obtained is from $1\frac{1}{2}$ tons to 2 tons per square inch. The cohesion is from 70 to 75 per cent, while the marine and State railway require from 50 to 60 per

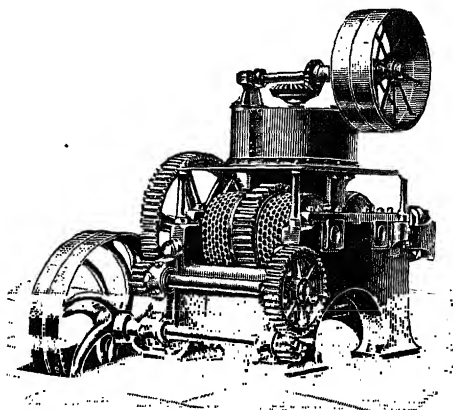


FIG. 31.—PRESS FOR OVOID-SHAPED BRIQUETTES

cent for their contracts. A central pitch crusher with spiral conveyor is provided for distributing the pitch to each set of presses. Each set is provided with two large storage bins for coal and one for pitch, as well as automatic feed measurers supplying coal and pitch in due proportions to the mixer.

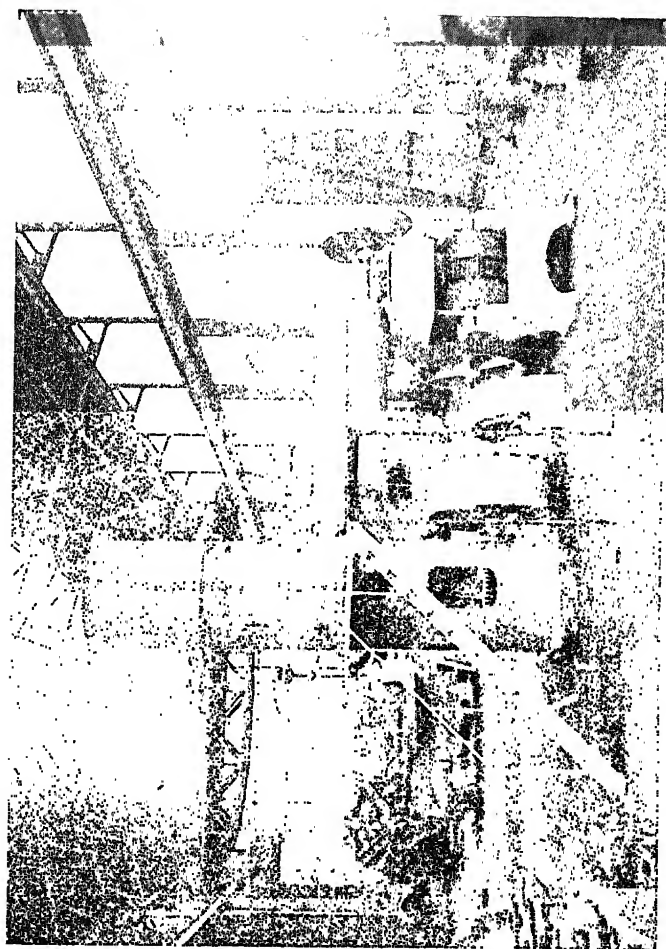


FIG. 32.—MALAXOR AND OVOID PRESS

The mixer is a special Carr disintegrator acting as mixer. The mixture is lifted by bucket chain elevator (Figs. 25-26) to a malaxor or pug (Fig. 32) provided with a special heating arrangement with superheated steam. The mixture under superheated steam is rendered fluid, and certain actions take place between the coal and the binder which increases considerably the cohesion obtained in the presses. From the pug the mixture is transferred by a spiral conveyor to the distributor fixed on the presses, and at the same time is submitted to the cooling action of a powerful fan, to be cooled to the proper temperature, which is, judged by experience, the most suitable for the compression in the press.

The stream of ovoids run from the press and are conveyed by endless belt to a trommel, where the edges are trimmed and any fragments removed, and then directly dumped into trucks or barges ready for transport.

The briquettes in the open mould are submitted to a prolonged pressure of about $1\frac{1}{2}$ tons per square inch, and are of great cohesion. They are received on an endless belt conveyor and transported directly to the railway trucks, and automatically tipped in.

The ovoids and briquettes are very stable and strong, cohesion up to 86 has been obtained, thus they can withstand any handling, and are waterproof. Very little labour is required for such large works, only 30 men being employed, and the cost of manufacturing this item alone is barely 6d. per ton, and in England would not exceed 1s. per ton. The horse-power required for the total plant dealing, say, with 100 tons per hour is 500. The plant is driven electrically, the power being obtained from the colliery central station. Each unit has independent service, and each special appliance has its own motor.

At the end of the Appendix the specifications of briquettes as laid down by the Ministry of Railways, Belgium, are given.

CHAPTER XIV

OIL SHALES

THE low temperature process, as now developed, is particularly applicable to the treatment of shales, torbanites, and similar carbonaceous material, and it will therefore be appropriate to introduce a brief reference to this aspect of the subject.

Extensive investigations were made during the war, by the Petroleum Research Department, into the material available in this country for retorting oil therefrom. The areas known to contain the largest and richest deposits of shales are situated in Scotland and Norfolk and Dorsetshire in England, but only in Scotland is productive work being carried on. As pointed out by Manfield, the oil shales of Great Britain are chiefly found in the carboniferous and Jurassic systems. In the latter the most important deposits are in the Kimmeridge clay, the lowest division of the upper Oolites. At Ringstead Bay, on the Dorset coast, the Kimmeridge clay can be traced from the Portland sands above it to the Coral Rag below. As it approaches the Coral Rag it becomes more gritty, and fossils belonging to the Coral Rag are found in it. Across the Channel at Boulogne, the whole of the Kimmeridge clay assumes this gritty condition from the Portland stone to the Coral Rag and no shales are found in it.

Dorsetshire.

The Kimmeridge clay has been estimated to be 900 ft. in thickness. In the southern part of the county the oil shales are exposed at the surface in two areas, one at Kimmeridge (round Kimmeridge Bay) and the other at Corton (some five miles to the north of Weymouth).

At Kimmeridge, the principal oil-bearing shale ("blackstone" or "Kimmeridge coal") is associated with several bands of shale of inferior quality, and is about 2 ft. thick and of a dark brown colour. It readily ignites, burning with a bright flame and giving off an offensive odour. It crops out on the crest of an anticlinal fold, which runs east and west in Kimmeridge Bay. On the northern side of the axis, it dips

from 15° to 20° beneath the Portland, Purbeck, and Wealden beds, on the south side dipping beneath the sea.

During the year 1917 a series of boreholes was commenced near Kimmeridge by the Department for the Development of Mineral Resources (Ministry of Munitions), and the results obtained are embodied in reports by W. T. Anderson and A. C. V. Berry to the Ministry of Munitions in February, 1918. The following figures have been extracted from these reports by the Geological Survey—

RESULTS OF SAMPLING AND TESTING KIMMERIDGE SHALES

	Depth.	Depth to Bottom of Principal Oil Shale.	Thick-ness Mined.	Volatile Matter.	Oil.	Ammonium Sulphate.
	ft.	ft.	ft. in.	per cent.	gal. per ton.	lb. per ton.
No. 1 Borehole . . .	108½	90	—	—	—	—
Overlying Shale and Blackstone conjointly.	—	—	4 5	24·0	26·5	20·4
Blackstone alone . .	—	—	2 6	34·6	40·6	22·7
No. 2 Borehole . . .	92½	77½	—	—	—	—
Overlying Shale and Blackstone conjointly.	—	—	3 4	32·5	32·1	27·5
Overlying Shale and Blackstone alone . .	—	—	2 2½	39·1	38·4	32·4
No. 3 Borehole . . .	290	48	—	—	—	—
Overlying Shale and Blackstone conjointly.	—	—	2 10½	27·7	22·3	28·6
Blackstone alone . .	—	—	2 2½	31·6	34·4	30·7

In an analysis by Berry, the sulphur in blackstone, Kimmeridge No. 1, amounted to 4·51 per cent.

ESTIMATES OF OIL SHALE AT KIMMERIDGE

	Thick-ness.	SHALE.		OIL.		AMMONIUM SULPHATE	
		Tons per Acre.	Total Tons in 2,900 ac.	Gall. per Ton.	Total Gall. in 2,900 ac.	Lb. per Ton.	Total lb. in 2,900 ac.
Shale . .	ft. in.						
Blackstone.	1 11	3,913	11,000,000	8·1	92,000,000	17·6	89,030
	2 6	4,375	12,000,000	37·6	363,000,000	28·6	161,820
Totals .	4 5	—	23,000,000	—	455,000,000	—	250,850

In the Corton area, an elongated area of Kimmeridge Clay stretches from Abbotsbury Station to Poxwell and Burning Cliff. On the south side of this are older rocks, whilst on the north there appear outcrops of Portland beds, Wealden and Purbeck beds, Chalk and Upper Greensand. The district is traversed by anticlinal folds, with steeply inclined northern limbs. In the neighbourhood of the great Ridgeway fault, which marks off the southern boundary of the chalk, the beds are vertical and disturbed.

The outcrop of the main oil shale has been traced from Portisham to Upway; but further to the east, and as far as Poxwell and Preston, its continuation has not been demonstrated by field-sections, although there are adequate data at hand from which it can be located. Poxwell Circus is a hollow denuded area in the crest of an anticline and surrounded by an escarpment of Portland stone. It is estimated that the depth of the oil shale is from 450 to 500 ft. below the centre of the Circus. At Black Head, west of Osmington Mill, the outcrop of the oil shale can be traced for a few hundred yards; and similar beds can be seen exposed in the face of Burning Cliff, which forms the eastern side of Ringstead Bay. Oil shale is also visible at Castletown, on Portland Island.

In August, 1917, several boreholes were started by the Ministry of Munitions near Corton, and the following results are recorded in the reports referred to in connection with similar investigations at Kimmeridge—

DETAILS OF BOREHOLES AT CORTON

	Depth.		Depth to Bottom of Principal Oil Shale.		Thickness of Principal Oil Shale.	
	ft.	in.	ft.	in.	ft.	in.
Borehole No. 1 . . .	65	1	54	8	2	0
„ No. 2 . . .	116	7	102	0	2	0
„ No. 3A . . .	42	0	24	9	1	9
„ No. 4 . . .	104	3	100	5	2	1

RESULTS OF SAMPLING AND TESTING CORTON SHALES

	Thickness Mined.		Volatile Matter.	Oil.	Ammonium Sulphate.
	ft.	in.	per cent.	gal. per ton	lb. per ton
<i>No. 1 Borehole—</i>					
Overlying Shale and Main Bed con-jointly	6	9	16.4	15.5	11.9
Overlying Shale and Main Bed con-jointly	4	2	18.9	15.8	17.3
Main Bed	2	0	29.5	25.5	28.5
<i>No. 2 Borehole—</i>					
Overlying Shale and Main Bed con-jointly	6	8	13.8	15.4	11.8
Overlying Shale and Main Bed con-jointly	5	3	15.4	16.3	12.0
Main Bed	2	0	22.75	28.1	14.6
<i>No. 3a Borehole—</i>					
Overlying Shale and Main Bed con-jointly	6	0	14.5	13.9	14.6
Overlying Shale and Main Bed con-jointly	4	1	16.4	16.3	16.2
Main Bed	1	9	25.9	29.9	23.3
<i>No. 2 Borehole—</i>					
Overlying Shale and Main Bed con-jointly	8	1	16.8	13.4	18.0
Overlying Shale and Main Bed con-jointly	5	3	19.4	15.7	18.3
Main Bed	2	1	33.5	29.1	26.1
<i>No. 1 Incline Shaft—</i>					
Overlying Shale and Main Bed con-jointly	5	10	—	14.6	—
Overlying Shale and Main Bed con-jointly	3	10	—	16.0	—
Main Bed	2	0	—	27.6	—

ESTIMATES OF OIL SHALE AT CORTON

	Thick-ness.	SHALE.		OIL.		AMMONIUM SULPHATE	
		Tons per Acre.	Total Tons in 1,500 ac.	Gall. per Ton.	Total Gall. in 1,500 ac.	Lb. per Ton	Total lb. in 1,500 ac.
Main Bed, with inferior shale	f. in.						
	2 0	3,500	5,000,000	28.0	147,000,000	26.3	61,500
"	4 0	8,300	12,000,000	—	—	—	—
"	5 0	10,300	16,000,000	16.3	253,000,000	15.1	105,000
"	6 0	12,000	18,000,000	15.0	271,000,000	13.2	106,500
"	8 0	17,700	25,000,000	—	—	—	—
"	10 0	21,000	32,000,000	14.0	442,000,000	13.0	183,000



FIG. 33.—MOUNT LOGAN, NEAR DEBEQUE, COLORADO, COMPOSED OF SHALES OF ALL GRADES

In an analysis by Berry, the sulphur in the main bed, Corton No. 2, amounted to 5.57 per cent (*see* table at foot of page 157).

The minerals known as torbanite, cannels, etc., although existing in this country in large quantities, occur in the coal measures and are difficult to obtain unless arrangements are made with colliery owners. Mr. E. H. Cunningham-Craig, in the *Petroleum Year Book*, 1923, on this subject, remarked that "Research quickly proved that the most hopeful and the most rapidly realizable method of obtaining oil lies in the retorting of these materials. The geological staff of the department visited practically every colliery in the country, and it was found that the quantity of valuable material at present neglected, whether mined and treated as waste or left in the mines, is enormous. In addition much valuable information was obtained about unworked or abandoned areas where valuable retortable material exists. In some cases it was necessary to descend the mines, but in most cases a study of the belts and waste heaps, and the cross-examination of managers, foremen, and miners was sufficient. Conservative estimates of available supplies were collected from each district and material selected for detailed examination. The detailed work consisted of microscopic examination, which resulted in the discovery of many important points and enabled a classification of all retortable materials to be made. Then came chemical analyses, and finally large-scale retorting tests were made of several tons of each deposit selected, to ascertain what conditions of temperature, etc., would give the best results in each case. The results were obtained and a complete record kept."

"This work resulted in the discovery that torbanites are much more common than had been previously supposed, while the various qualities of gas, splint, and cannel coals, as well as various other valuable materials known by local names such as 'batts,' 'jacks,' 'gees,' 'rattle-jacks,' 'rums,' etc., were recognized, classified, and their potential yields of oil determined."

The average production of oil from the material selected for treatment was from 33 to 35 gallons of crude distillate per

ton, and from this distillate at least 10 per cent of petrol can be obtained by refining.

Oil shale is deposited in enormous quantities in the United States, the chief of these being in Colorado and estimated by the United States Bureau of Mines to cover an area of 900,000 acres. The deposits of north-west Colorado, Green River formation, are stated to exceed in average richness per acre that of any other deposits in America and probably in the world. Shale is indeed a mineral which occurs in greater or less quantity and quality in every country, but many of these are not profitable to work on account of their geological position and their poorness in oil content.

Among the deposits which have come into notice recently are those of South Africa, Nova Scotia, Esthonia, and Australia.

South Africa.

The oil shale deposits so far discovered crop up in various isolated spots in the largest coalfield in the Transvaal, extending nearly from the Wilge River, Swaziland, on the one hand, and from Volksrust to Middleburg on the other, and generally referred to as the Great Eastern coalfield. The principal deposits of oil shale discovered occur in the Ermelo district, between Ermelo and Carolina, but they also exist between Ermelo and Wakkerstroom, and to a less extent, in the Middleburg district.

In the Ermelo district, torbanites are interspersed generally among veins of highly bituminous coal, with a clear cleavage from the latter. The torbanite yields on distillation from 135-140 galls. per ton, and the coal from 20-30 galls. per ton. For industrial purposes, the coal and torbanite treated together would yield between 50 and 60 galls. per ton of material. Of this material, there exist particularly large areas already developed; and of pure torbanite it is estimated there are available on one property alone 8,000,000 tons, and of coal, approximately 100,000,000 tons. Of these quantities, about 25,000,000 tons are opened up for mining.

Distillation work on the coal has already been commenced

in India, whence the coal is shipped, and both briquettes and ovoids are being made from the residue fuel.

The residue from the combined torbanite and coal, and yielding 60 galls. of oil, provides an ideal material for briquetting, giving a high calorific power and being entirely smokeless.

The total area of oil shales and torbanites in South Africa

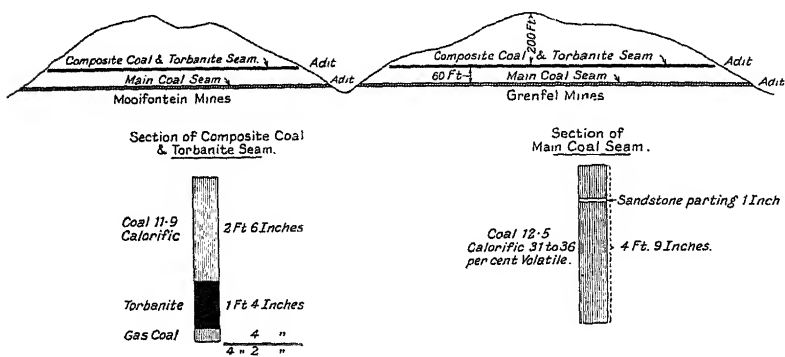


FIG. 34.—SECTION SHOWING OCCURRENCE OF COAL AND TORBANITE AT ERMELO, EASTERN TRANSVAAL

is sufficiently large to provide the requisite quantities of oil, motor spirit, etc., for the Union for generations to come.

The nature of the occurrence of these minerals in South Africa is so remarkable that we think it is of sufficient interest to illustrate this.

The Australian shale occurs along with coal in similar manner to that at Ermelo, but is generally thicker, running to a thickness of over 6 ft. in many instances. On distillation, the Ermelo crude oil yields the following percentages of finished products: naphtha, 3.9 per cent; paraffin oil, 26.3 per cent; lubricating oil, 30.7 per cent; paraffin scale, 10.1 per cent.

New Brunswick.

The New Brunswick shales are somewhat similar in character to those of Scotland, the strata embodying the seams belonging to the rocks of the upper Devonian system which is overlaid

by rocks of the low carboniferous series. Large deposits have been proved in Albert and King's counties. The seams of shale in some parts aggregate a thickness of 200 ft., and analyses have proved that the best shale yields from 40 to 50 gallons of crude oil per ton and from 77 to 110 lb. of sulphate of ammonia per ton.

Nova Scotia.

In Nova Scotia the deposits are of the torbanite description and are of great extent. An estimate places the deposits in and around McLellan's Brook at 100 million tons of shale readily accessible by mining or open-cast working over an area of 2,000 acres. The field itself extends over an area of 10,000 acres and the most recent investigations indicate that no less than 2,000 million tons of torbanite are available.

Analyses have shown that the crude oil yields from various samples range from 38½ gallons to over 60 gallons per ton of material.

The following results of a distillation run of crude oil from this torbanite compared with Mexican crude oil is given as follows—

TEST OF OIL SHALE

Specific gravity, .852.

Distillation run, compared with crude petroleum—

Temperature.	Shale Oil.	Mexican Crude.	Mexican Crude.
°F.	%	%	%
142	—	I.B.P.	—
152	—	—	I.B.P.
180	I.B.P.	—	—
221	5.0	3	—
284	6.5	5.0	—
350	10.5	11.0	—
374	12.0	13.0	14.0
400	14.0	15.0	—
437	19.5	17.5	—
460	21.0	21.0	29.0
500	25.5	24.0	—
560	34.0	30.5	52.0
600	39.0	46.0	59.0
Water	.5	—	5.0
B.S.	.3	.75	—
Sulphur	—	—	—

Australia.

The oil shales of Australia are extensive and well known, although these are not being developed at the present time, though no doubt, with the introduction of the modern low temperature retort, work will be recommenced. The average yield of oil from the shale in 1922 was about 100 gallons to the ton, 24,728 tons yielding 2,535,369 gallons.

Esthonia.

The oil shales of Esthonia occur in the Cambrian, Silurian, and Devonian formations, and in a paper read by Mr. E. H. Cunningham-Craig before the Institution of Petroleum Technologists some interesting data relative to the shales in the northern part of the country are given.

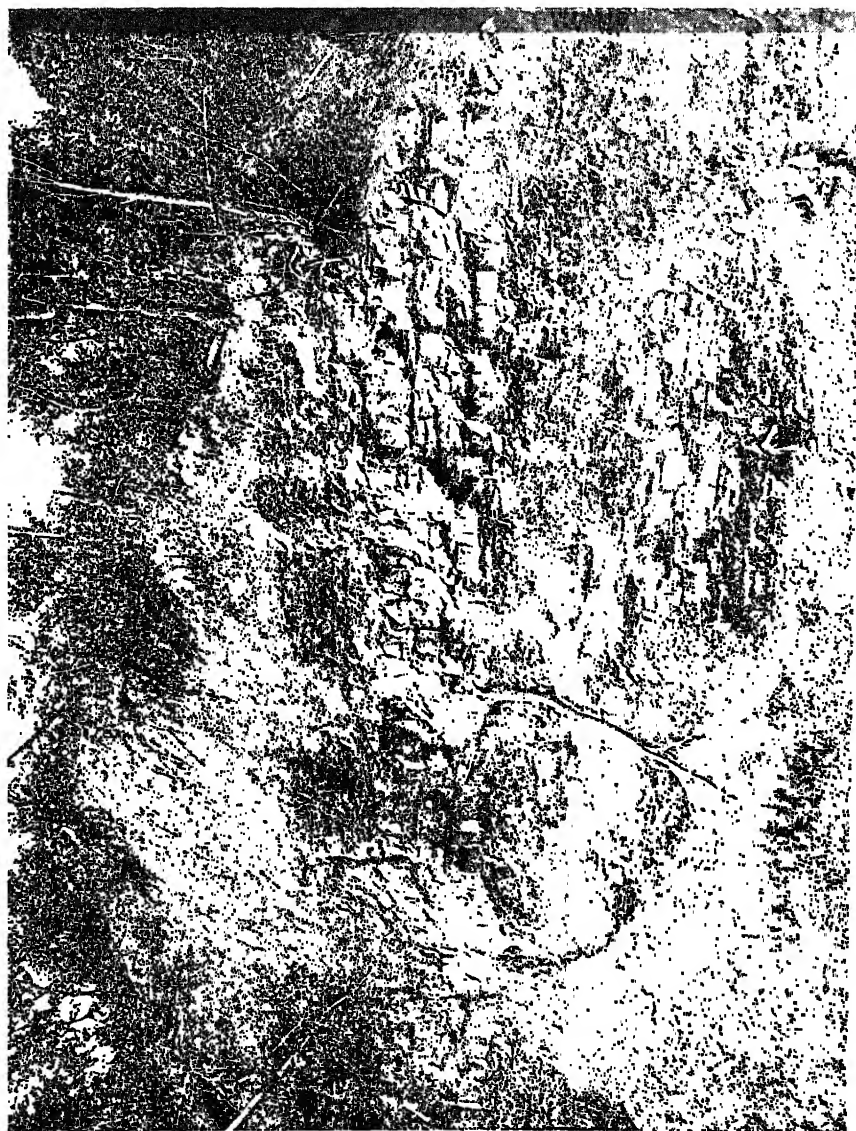
The Cambrian is only exposed, he remarks, along the northern coast and along river valleys. Practically the full thickness has been proved by borings, and a typical section is as follows—

	Ft.
Dictyonema shale	3
Glauconitic sandstone	11
Dictyonema shale	30
Sandstone	83
Clay (variegated)	150
Conglomerate and sandstone	340
	<hr/>
	617 ft.
	<hr/>

From a series of analyses made in the Central Laboratory of the Esthonian Republic, the composition of the mineral matter is given as follows—

	%
Silica	32.74 or less
Alumina	15.76 „
Iron oxide	1.68 „
Lime (or Calcite).	49.64 or more
	<hr/>
	99.82
	<hr/>

This is a very high percentage of lime, almost all of which may be put down as fossil debris. Other analyses of dried



material give magnesium and sodium and potassium, taken together, 0.4 per cent, and water, 1.2 per cent.

There is a distinct resemblance, so far as conditions of deposition are concerned, between the oil shales of Esthonia and those of Dorsetshire and Norfolk, except that in these cases the environment was argillaceous rather than calcareous, and the resulting shales muddy with occasional sand grains.

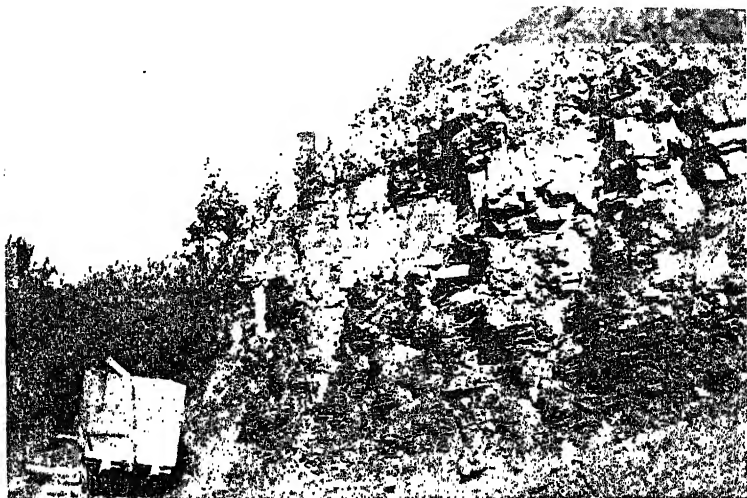


FIG. 36.—SURFACE EXPOSURE OF TORBANITE, NOVA SCOTIA

The volatile percentage has been given as anything between 52.5 per cent and 65 per cent, while "coke" or "fixed carbon" is stated at from 5 to 11 per cent. The reason for these differences is that if quickly subjected to a high temperature destructive distillation takes place with the deposit of free carbon; later, at a higher temperature, the free carbon, finally divided and closely associated with calcium carbonate, reacts with it, giving off carbon monoxide and thus increasing the volatile percentage, which, of course, also includes the moisture present.

From the data available it seems that we may take the average volatile percentage at from 54-56, which is



FIG. 37.—SHALE AT TURPSAL ESTHONIA, SHOWING
LIMESTONE BANDS

extraordinarily high for a shale. Analyses of the organic contents by different authorities give the following—

		%	%
Carbon	. . . . .	70.52	72.82
Hydrogen	. . . . .	7.20	8.66
Nitrogen	. . . . .	0.30	0.68
Oxygen	. . . . .	21.98	16.24
Sulphur	. . . . .	—	1.60

The sulphur percentage, 1.60, is not high for such material and compares favourably with Dorset and Norfolk shales. The shale has been tried in many forms of retort with varying results, but from the writer's experience of the tests made, he is convinced that the best results cannot be obtained in any vertical retort, with or without steam. Perhaps the most unsatisfactory attempt at distillation of this material is that in a German vertical retort now in operation in Esthonia. It yields from 40 to 50 gallons per ton of an oil of 0.98 sp. gr., a yield in works practice of between 70 and 80 gallons per ton, and a crude oil not higher than 0.93 sp. gr. can be counted upon with confidence.

It is interesting to note that shales in Esthonia have been used in a pulverized form for fuel purposes by being blown into a rotary furnace. It is stated that the Esthonian cement factories have been using no other fuel for the last two years.

Italy.

In Italy¹ there are considerable deposits of easily accessible bituminous shale in the province of Messina in Sicily. In Germany there are extensive deposits in the Rhine provinces, in Hesse, Wurtemberg, Baden, and Bavaria. Oil was obtained from these in the past, and the industry only drooped in competition with the United States. Should their production fall, and we contend that it is practically so doing, all these deposits which are said to have averaged a production of 16 gallons to the ton, now by modern methods largely to be increased, should again re-open with very beneficial effects to civilization and profit to the country concerned.

¹ Paper read by Mr. E. H. Cunningham-Craig and Admiral P. W. Dumas, International Oil Congress, Paris, October, 1922.

Spain.

In Spain there are immense deposits only to be computed in hundreds of millions of tons. The yield in the past has been small (stated to be but nine gallons to the ton), but this in any circumstances is ridiculous, and modern methods are certain very largely to increase it.

Sweden.

In Sweden the deposits are estimated to contain over 5,000 millions of tons of a valuable type.

Switzerland.

In Switzerland there are huge deposits of oil sands and bituminous and carbonaceous shales, tests of which give 14 to 15 gallons of oil per ton, and other reports give a yet higher yield. Surely, with latter-day methods, here again is a field to be commercially exploited.

Jugo-Slavia.

In Jugo-Slavia oil shales are reported to occur on a large scale and of a highly valuable nature, report speaking of 45 gallons of oil to the ton.

France.

The deposits of the Saône-et-loire Department, in the basin of l'Autunois, are, says M. Brunschweig, the most important, and are the only ones actually exploited. They are situated in disturbed permian carboniferous strata, and some 20 beds of from 1 metre to 4 metres in thickness are exploitable. The ton of shale yields 90 litres of crude oil and 12 kilogrammes of sulphate of ammonia. The area of the field is 8,000 hectares. The production in 1913 was 127,000 tons, but in 1921, 63,000 tons only. The deposits in Allier, in the valley of the Aumance, are rather irregular, and from 1 metre to 2.20 metres in thickness. The yield is 70-80 litres of crude oil and 8 kilogrammes of sulphate of ammonia per ton. The production was 60,000 tons yearly before the war, but has now ceased. In the Var, in the Frejus Valley, there is an exploitable deposit 1.50 to 2.00 metres in thickness. In La Vendee, in the Faymoreau

basin, there is a little explored layer of oil shale 2 metres thick. In Ardeche are the two Vaghas deposits, each 1.50 metres in thickness. The extent of the deposits is being explored. In Cantal there are the Vendes shale beds, which are almost vertical and about 10 metres in thickness. Little is known of the extent of these deposits. The total reserves of French oil shale, taking into account only the best-known and most accessible deposits, are estimated at about 50 million tons, of which more than half are situated in the basin of the Autunois.

Russia.

The oil shales appear in Russia in many formations, but mainly in the Jurassic. The principal districts in which they are found are the middle and lower Volga valley, and the district between this and the Ural river. This district comprises the most important shale deposits, which are at Simbirsk, and those at Sysran and Obshe Syrt. The Simbirsk deposits, in the lower Volga beds, occupying the area of the Volga-Swiagi watershed, are almost horizontal, and are covered by more recent sedimentary rocks. They extend from 7 km. about Simbirsk for a distance of 30 km., and are found in dark clayey shales, interbedded with clayey loam. Above the shales lie the Glauconite sands and phosphorite layers of the upper Volga beds. The amount of shale is estimated at 20,000 million poods. The content of volatile matter is 20-33 per cent, and the yield is on an average 10 per cent of oil. Deposits of less magnitude are found at Buinsk-Sergatsh, Sysran, Sheguli, and Obshe Syrt. Oil shales are also found in the middle Jurassic formation in the Ural River district, in the tertiary of the Volga-Kama district, in the Viatka-Vologda district, and the western slopes of the Ural Mountains (Devonian and carboniferous). The Volga shales of Simbirsk and Sysran have been exploited since 1920.

Chile.

Large deposits of shale are also found in Chile on the Argentine frontier, estimated to amount to 18,000 million tons. The yield of oil is not so good as in the shales already

referred to, averaging over 19 samples tested 16·8 per cent, the lowest being 12 per cent and the highest 24·5 per cent. The crude oil has a gravity of ·924, but after drying the shale, the specific gravity of the oil was ·887.

The oil shales of Chile occur chiefly between the Cretaceous and Miocene formations. The deposits near Pular, from which nineteen samples were taken and distilled, showed that the oil contents of the shale were as follows—

OIL CONTENTS OF 19 SAMPLES OF SHALE OBTAINED
BY DIRECT DISTILLATION

No.	Oil.	No.	Oil.	No.	Oil.
	%		%		%
1	20	7	12	13	14
2	18·4	8	14·4	14	16
3	18·8	9	24·5	15	16
4	16·5	10	24·0	16	24
5	14·2	11	17·0	17	14·5
6	18·2	12	14·4	18	12·0
				19	12·5

The fractional distillation of the crude oil carried out by Mr. Oswald H. Evans, of Valparaiso, gave the following results—

Below 100° C.	. . . . .	%
100° C.—150° C.	. . . . .	8
150° C.—200° C.	. . . . .	12
200° C.—250° C.	. . . . .	18·0
250° C.—300° C.	. . . . .	20·0
Residue in retort, solid and pitch-like on cooling	. . . . .	38·0
		4·0
		<u>100·0</u>

The heavier fractions are rich in paraffin wax.

American Distillation Practice.

The evolution of oil shale distillation plant in the United States is traversed by Dr. David T. Day, and indicates clearly the weakness of early methods and the lines on which the modern retort is being designed.

Processes for the retorting of American shales, he states, may be grouped under three classes: First, those, like the

Scotch retorts, which deal with the fall by gravity of the shale in some vertical form of retort ; second, those of the screw-conveyor type, in which the shale, heated in a horizontal tube, is carried along by a screw conveyor or system of paddles or some similar form of propulsion—such systems were successful in the United States as far back as 1850 ; third, those retorts, usually horizontal, which resemble the modern cement roasting kiln, consisting of a revolving cylinder, usually provided with a helical arrangement on the interior surface, by which the shale is propelled by the revolving of the retort itself. The shale is heated externally or internally, the oil being extracted in the time of passage from the inlet end to the outlet.

It is interesting, in this race for success, to note that a representative of each class has emerged from the mass, and that all three classes have representatives which are nearing the finishing point. Thus, the example of the Wedge roasting furnace, originally designed for the oxidation of copper sulphide ores, pyrite, etc., has been made to evolve several forms of shale furnace, of which the Day-Heller and the National, the Hartman, the Trent, and other similar furnaces have been the farthest developed. These are vertical furnaces, in which the shale enters at the top, falls by gravity, and is taken away as spent shale at the bottom. They all try, however, to prevent the choking of the retort by the device of introducing shelves, which either revolve or are fitted with revolving arms so that the shale falls from one shelf to the other, and much space is left between these shelves for the free upward flow of the vapour and gases formed.

In spite of the successful use of conveyors of the helical screw type and other forms of conveyors in the old days before the advent of oil from wells, these horizontal retorts did not meet with favour in Scotland, and they have been subjected to two kinds of adverse criticism in the United States. The first objection was due to ignorance of the fact that if a screw conveyor propels shale through a horizontal tube, the least amount of plasticity tends to make the shale stick at some part of the journey. A very slight blocking of the tube by this means is amply sufficient to stop the screw, when the sticking immediately becomes an insuperable obstacle. The retort

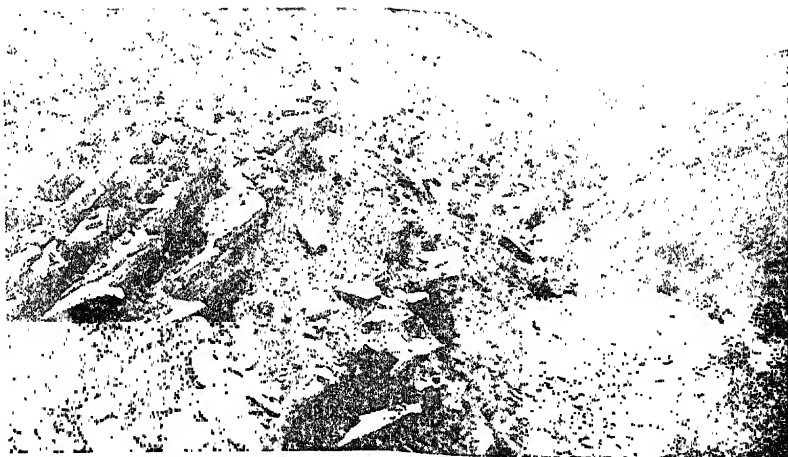


FIG. 38—SHALE DEPOSITS IN CHILE

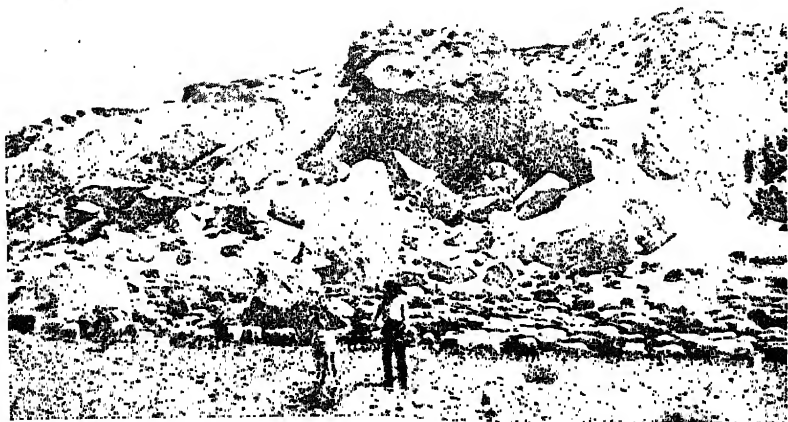


FIG. 39.—SHALE DEPOSITS IN CHILE

must then be shut down, and the shale taken out by hand, with great loss of time and energy. Aside from this liability of the shale to stick and thus clog the tube, there is the difficulty of heating horizontal tubes in any economical way by which the flow of heat from the products of combustion through the iron tube into the shale is sufficient for the distillation. It has become obvious that any tube over 10 in. in diameter can only



FIG. 40.—OIL SHALE DEPOSITS, KENTUCKY

be heated with extravagant waste of fuel. On the other hand, tubes smaller than this, with greater heating efficiency, will only take a very thin line of shale, and the throughput is not sufficiently great to be interesting.

Cement Kiln Type.

Concerning the cement kiln type of shale furnace, of which the Ginet is a typical example, this is usually heated from the outside, and being comparatively large in diameter, exposes too little heating surface per ton of shale for economical results. Other types, as in a modern cement kiln, are heated internally. In such a system the entire gaseous products of

combustion, usually from an oil burner, pass through the shale itself, heating it quite efficiently. The products of combustion pick up the volatilized oils, water, etc., from the shales and carry them through to condensers, which are supposed to scrub out the oil vapours.

The doom of these processes is, in the writer's judgment, sounded by the fact that in most cases 20,000 cu. ft. or more of products of combustion, together with the permanent gases formed in the distillation of the shale, will traverse every ton of shale and go out charged with the oil vapours. The difficulty of successfully condensing out the oil from this enormous amount of permanent gas is as yet unsurmountable, the result being that should the effluent gases contain no more than one-half gallon of gasolene per 1,000 ft. of gas, there would be a waste of practically all the gasolene which a shale oil would be able to furnish. Thus it is easy to see the loss of at least 10 gallons of gasolene per ton of shale. An extremely costly system of condensation, either by compression and cooling or by absorption, would be necessary to recover this amount of gasolene. It does not seem reasonable to the writer that good results can be expected when the shale vapours are exposed to any such volume of permanent gas.

No one can yet predict whether the Wedge furnace, or vertical retort, as exemplified by the retort of the Day Engineering Company and the National retort, will prove more efficient than the screw conveyor method of heating. It seems probable that other features must now enter into consideration, and that these will eventually determine the superiority of one form over the other. It is obvious that economy of fuel is the crux of the whole matter. There have been cases beyond doubt in the United States where the fallacy of a process has been evinced by the necessity of burning a barrel and a half of oil to distil a barrel of oil by the process in question. Fuel economy is seldom considered in the experimental stage. It is summarily dismissed in most cases by the statement that "the permanent gas obtained is amply sufficient for the fuel requirements of the process." And this statement is made usually on the basis of pure assumption, with no quantitative data applicable to a retort of commercial size. And yet the

experience of 75 years of steady technologic progress in the Scotch oil-shale fields has failed to develop any retorting system which could safely rely upon its permanent gas as its sole source of fuel. In this regard, one must remember the sagacity with which the Scotch have continually improved fuel efficiency, often to the extent of dropping the spent shale from the distillation zone directly at its high distillation temperature into a gas producer zone, where, with the aid of steam, as in the Pumpherson process, the residual carbon is immediately converted into carbon monoxide and hydrogen, and this, sweeping out the vapours from the upper portion, has carried these vapours forward to the condensation apparatus, mixed with as much as 14,000 to 16,000 cu. ft. of combustible gas per ton of shale put through. The writer can speak with authority after the experience some years ago with the erection of a Pumpherson furnace in the United States. While he came *near* achieving fuel independence through the permanent gases produced, this goal was never reached.

Use of Spent Shale.

On the other hand, the simple expedient developed by the late Mr. J. H. Galloupe was to the effect that when the American shales of the Green River type are retorted in a vertical retort of his construction, and the spent shale dropped into a combustion chamber, the hot shale took fire as soon as it came in contact with the air. It burned readily, on account of its porosity, and gave ample heat for the distillation of the shale. The effect of this upon American experimentation was immediate, and many others, including the writer, are applying with good results the simple method of burning these porous spent shales under the retorts. The effect has been to give predominance to the small horizontal tube, in connection with which it is a simple matter to pass the spent shale along on a chain stoker underneath the long horizontal retorts. The products of combustion are applied at once to heating the horizontal tubes, which usually number six or twelve. They are arranged vertically above each other, the shale dropping from one tube to the one below it, and finally to the

ombustion chamber. A modification of this in the Day plant will be referred to later on.

The Catlin plant, at Elko, Nevada, is in a class by itself. It utilizes a shale which yields an unusually large percentage of paraffin wax. Dr. Alderson describes the plant as follows¹—

“The underground development consists of an incline 500 ft. long with drifts at each hundred feet extending 500 ft. each way from the incline. The daily production is 100 tons. Two new circular vertical retorts, each 14 ft. in diameter and 17 ft. high, are now in operation. The surface equipment includes an 8,000- and a 6,000-barrel tank for crude oil, two 100-barrel stills, a refining plant using the standard acid and soda method, and a wax plant. The shale yields 40 gallons to the ton of oil. The products are gasolene, lubricating oil, and wax.”

Heat Exchanging System.

The chief obstacle in distilling oils from shales is due to the poor heat conductivity of the shale itself. With shale broken to 2-inch diameter, or even smaller, the surface of each fragment must be heated far beyond the distillation temperature if the heat is to reach the centre of the fragment rapidly. It occurred to the writer that the cold raw shale might be conveyed through a series of tubes exterior to the furnace and that the oil vapours from the retort could be passed over and through the raw shale, heating the shale and cooling the vapours.

D. T. Day System.

This, as built and in operation at Casmalia, California (*see* page 179), consists of two series of six horizontal retort tubes, 12 ft. long and 10 in. in diameter, set in a brick frame in which baffle arches direct the fire along the tubes and eventually to the stack. The top retorts are connected to a preheating system of three tubes, 10 ft. long and 15 in. diameter, slanting upward towards the furnace at 10 degrees. The raw shale is fed at a regular rate into the first tube through an oil seal. A screw conveyor carries it up to drop into the low end of the second similar preheater, which in turn delivers it into the third,

¹ *Colo. Sch. Mines Quarterly*, Jan., 1923.

thence into the top furnace tubes. Here screw conveyors take the shale to the opposite end, where it drops to the tube below. It is then conveyed back to the opposite end, where it falls to the next tube below, finally falling through a revolving valve on to a Laclede-Christy chain stoker. The shale, now spent, takes fire and furnishes more heat than desired for the distillation. Therefore, a series of half-inch pipes is introduced along the lowest retorts to use the surplus heat in superheating steam which enters the retort system at the bottom. The burned spent shale is carried mechanically to a stacker.

The vapours travel out in the inverse direction to the shale, and passing into the preheaters are partially condensed, forming a bath of hot oil, through which the shale passes. This is most important, as it serves to drive off the large percentage of water characteristic of the Monterey shale. An overflow pipe from each preheater takes away the surplus oil that condenses. Inasmuch as this so-called Monterey is really only oil-soaked diatomaceous earth, the solvent action of the hot light oil is considerable and extracts much oil without the necessity of distilling it.

The condensation and separation of the water and oil has nothing new. The permanent gases are burned to produce steam for pumps, etc. In the early stages of the plant a forced draught was blown under the grate, and steam injectors were used in the rather small stack, but all this has proved unnecessary. The oil as produced contains about 30 per cent of gasolene (spirit) and a small quantity of crude gasolene is also obtained as drips from the permanent gas.

In regard to the cost of working an American plant by the Continental Shale Products Company of California, Dr. David T. Day provides the following table which throws very interesting light on American conditions in the oil-shale industry.

ESTIMATED CONSTRUCTION AND EQUIPMENT COSTS
PER 1,000-TON PLANT

	\$	\$
MINING AND HAULAGE—		
Drills, Mining Equipment, etc.	1,500	
Gathering and Loading Equipment	3,000	
Conveyance to Crushing Plant	10,000	
	<hr/>	
		14,500

ESTIMATED CONSTRUCTION COSTS—(cont.)

CRUSHING—	\$	\$
Crushing Equipment	13,000	
Conveying and Feeding	12,000	
Electrical Equipment and Installation	3,500	
Transmission Equipment	1,500	
Primary and Secondary Bins	30,000	
Screens and Grizzlies	800	
	<hr/>	60,800
RETORTING PLANT (Equipment and Installation)—		
Five Sets Double Retorts and Reheaters	75,000	
Transmission	2,000	
Electrical	3,000	
Conveying and Feeding	2,500	
Spent Shale Disposal	1,000	
Condensers and Storage	9,000	
	<hr/>	92,500
TREATMENT, INCLUDING STORAGE—		
Topping Plant	6,000	
Absorption Plant	1,000	
	<hr/>	7,000
MISCELLANEOUS—		
Office	1,000	
Look House	400	
Machine Shop and Equipment	1,000	
	<hr/>	2,400
Total		177,200
Errors and Omissions 20%		35,440
GRAND TOTAL		<u>\$212,640</u>

ESTIMATED DAILY COSTS FOR 1,000-TON SHALE PLANT

This estimate is figured for the Casmalia Plant only and includes labour, power, and supplies for operation and maintenance.

	Per day. \$	Per ton. \$
Mining	123.35	0.125
Gathering	52.00	0.052
Haulage and Grizzly	26.75	0.027
Crushing	54.80	0.055
Retorting	144.50	0.144
Spent Shale	30.10	0.030
Absorption	31.00	0.031
Foreman	18.00	0.018
Office and Warehouse	15.00	0.015
Taxes and Insurance	20.00	0.020
Interest at 7%	46.25	0.046
Amortization over 25 years	27.00	0.027
Depreciation (10 years)	66.50	0.067
Miscellaneous	40.00	0.040
	<hr/>	<hr/>
Errors and Omissions, 20%	695.25	0.697
	139.05	0.139
GRAND TOTAL	<u>\$834.30</u>	<u>\$0.836</u>

SUB-DIVISION					ESTIMATED DAILY COSTS—(cont.)			
					\$	\$	\$	\$
Operating—								
Labour .	.	.	.	.	255.00		0.255	
Power .	.	.	.	.	38.70		0.039	
Supplies .	.	.	.	.	170.75		0.171	
						464.45		0.465
Maintenance—								
Labour .	.	.	.	.	49.50		0.049	
Supplies .	.	.	.	.	177.75		0.177	
						227.25		0.226
Total Labour .	.	.	.	.	304.50		0.304	
Total Power .	.	.	.	.	38.70		0.039	
Total Supplies .	.	.	.	.	348.50		0.348	
Total Overhead .	.	.	.	.	161.05		0.161	

Total men employed per 24 hours . . 140

The Day-Heller retort uses both gravity and mechanical means to keep the shale moving. The retort shown in the illustration (page 51) employs slanting hearths, down which the shale moves by gravity. A revolving inner member serves to keep the shale agitated and prevents sticking and clogging. This type of retort includes most of the factors essential to perfect retorting and shows promise of commercial success.

CHAPTER XV

LIGNITE

PROBABLY the largest deposits of lignite in Great Britain are those found in the tertiary basin of Bovey Tracey in Devonshire. This is a roughly rectangular pocket of tertiary strata in the valley of the Teign and its tributaries, the total area being upwards of 12 square miles. Lightly compacted sands and gravels and fine clays with a number of lignite beds have accumulated in this basin to a depth of upwards of 600 ft., and possibly, in places, as much as 1,000 ft. Only those beds of lignite nearest to the surface have been worked, and that never on a large scale. There are several beds in this neighbourhood, but they appear to be splitting up and thinning out among arenaceous sediments towards the margin of the basin.

A boring made many years ago at Heathfield, towards the centre of the basin, proved the lignite series to a depth of over 600 ft., and pierced one solid bed of lignite 30 ft. in thickness, as well as many thin beds alternating with clays. There is every probability of the central part of the basin, over an area of three or four square miles, containing thick and solid beds of lignite, but a series of bore-holes will require to be made to prove the full extent of these carbonaceous deposits. It is interesting to note that montan wax has been extracted in payable quantities from this material.

The only other lignite basin of any great extent in these islands is that of Lough Neagh in Ireland. The lough lies in a depression in the basalt plateau, and is surrounded by low-lying land formed of tertiary strata. Among these tertiary rocks two seams of lignite have been proved, one of which is said to attain a thickness of 25 ft. The area is large, and has never been fully prospected by boring except in one locality.

The quality of the lignite seems to be very similar to that of the Bovey Tracey basin, but once again deeper exploration may result in the discovery of more valuable material.

In Dorsetshire the tertiary basin contains thin lignite seams, which, however, have never been put to any use except locally to a very small extent for fuel.

SURFACE LIGNITES

Water.	Fixed Carbon.	Ash.	Volatile.	Volatile in Residue.	Crude Oil.	Sp. Gr. of Oil.
%	%	%	%	%	Gall. per ton.	
35·6	38·1	20·9	41·0	13·4	12·3	1·000
37·1	45·8	19·2	35·0	3·0	17·0	·999

At Halle in Saxony, and Messel, near Darmstadt, there are 12 works, together working over one million tons per annum, producing 60,000 tons of oil, and 7,000 tons of paraffin wax, equivalent to 18 gallons of oil per ton.

The result of investigations in Germany, and the elaborate experiments and methods developed at the School of Mines of the University of Dakota, leaves little doubt that the extraction of oil, and briquetting of the residues, together with the production of gas, has proved to be a great success, the composition of the lignite treated being—

Moisture	%
Volatil matter	12·01
Fixed carbon	29·19
Ash	55·00
	<u>3·80</u>
Calorific power	99·35 B.Th.U.

The temperature is 500° C. The gas produced from moisture is reheated by circulating under the floor of the oven and through the coal. After stripping, the yield of gas is about 10,000 cu. ft., and 13 gallons of oil per ton and 2½ lb. of ammonia sulphate per ton, the coke, 1092 lb. per ton of coal used.

Owing to the high pressure employed there is a large amount of gas produced and the oil products are fairly acid. The use of steam and lower temperature would give a result more in keeping with the German yield of 18 gallons per ton.

The coke is turned into briquettes, using as a binder the heavy oils and pitch obtained. The oils give by fractioning : 150° C., 14 per cent light oils ; 150°–325° C., 58 per cent heavy oils.

The residue, 18 per cent, is a hard black pitch used as the binder for the briquettes. The composition of the briquettes is—

	%
Moisture	1.34
Volatile matter	7.00
Fixed carbon	84.04
Ash	7.02
	<hr/>
	99.40%
	<hr/>

The calorific power is 14,061 B.Th.U. The pitch C.P. is 18,000 B.Th.U. The pitch is an oil pitch; 99 per cent is soluble in carbon sulphate.

France.

France, not being richly endowed with coal, but possessing extensive deposits of lignite, is now being exhaustively examined by a Government Commission as to the ways and means to be adopted for their active development. The lignite is rich in oil which can be distilled, and from the residue obtained high grade briquettes can be produced.

Apart from the deposits known to exist in Alsace, the principal French fields were described briefly by M. Brunschweig at the International Oil Congress, Paris, 1922.

The principal fields are as follows—

THE FUYEAU BASIN (BOUCHES-DU RHONE). The field is situated in neocretaceous strata, and has an area of 1,000 square kilometres. There are three principal regular beds of a thickness of 0.5 to 3 metres. The exploitation by shafts and galleries is carried on to a depth of about 250 metres. The fuel is black, of a bright fracture, and contains 8 to 9 per cent of moisture and 6 to 20 per cent of ash. The yearly production in 1920 was 665,000 tons.

THE BASINS OF THE COMTAT (GARD, ARDECHE, VAUCLUSE). This is a group of secondary and tertiary basins, the principal being the basin of Bagnols, with two to five beds of .50 to 2 metres thickness; the lignite is of an earthy appearance, and contains 15 to 30 per cent of ash; the basin of Alais, with two or three beds of 0.80 to 4.50 metres thickness, moisture content, 10 to 20 per cent, ash content, 13 to 20 per cent; the

basin of Methamis, three beds of 0.60 to 1.50 metres thickness, lignite dull black, friable, containing 17 to 22 per cent of moisture, and 14 to 30 per cent of ash. The total production of the Comtat fields in 1920 was 120,000 tons.

THE BASIN OF MANOSQUE (BASSES-ALPES). The strata are oligocene and contorted. Three superincumbent beds of 0.50 to 1.0 metres thickness. The beds are often greatly inclined, water content 3 to 20 per cent, and ash content 15 to 40 per cent; annual production for 1920, 71,000 tons.

THE LANDES BASINS. First, the Basin of Lалуque, in the pliocene. A bed 1 to 6 metres in thickness, lying under 6 to 20 metres of overburden; lignite woody or earthy, containing 44 to 55 per cent of water and 5 per cent of ash; second, the San-Lon basin, in the eocene; two beds of 0.80 to 2 metres thickness, lignite black and shiny, containing 20 per cent of water and 10 per cent of ash. Total production of the Landes basins for 1920, 28,000 tons.

THE SARLADAIS BASIN (DORDOGNE). One pretty regular bed of 1.50 to 2.0 metres thickness; 21 to 27 per cent water content, and 7 to 15 per cent ash content; production in 1920, 10,000 tons.

LA CAUNETTE BASIN (AUDE, HERAULT). Very irregular lignitic strata; number of beds irregular, thickness 0.50 to 4 metres; water content, 2 to 10 per cent; ash content, 22 to 40 per cent; production in 1920, 3,000 tons.

There are also the Basins of Larzac (Aveyron), Estevar (Basses-Pyrenees), and numerous beds in the Alps, notably that of Voglans. The total production of lignite in France has been—for 1913, 793,000 tons; for 1918, 1,317,000 tons; and for 1920, 960,000 tons. The Basin of Fuveau accounts for 70 to 85 per cent of the total. The products of this basin resemble coal in many respects. The estimates of the reserves of lignite in France vary between 1,000 and 2,000 million tons, of which the Fuveau field represents about 50 per cent.

Low Temperature Plant at Denver, Colorado.

As reference has been made to this system, it may be well to include a short description of what has been done in America on the initiative of Mr. Charles A. Hoover.

This plant has been constructed in Denver for the production of briquettes, gas, light oils, creosote, pitch, and ammonium sulphate from Colorado lignites. The briquettes and ovoids are of good quality, and contain slightly over 14,000 B.Th.U. per lb.

The gas evolved is at present in large part wasted, but it could be eventually utilized commercially, or, better still, its production considerably reduced by further lowering the temperature at which the plant is operated, and in using superheated steam, as will be done in a new retort constructed by a Luxembourg firm for the treatment of the lignites of the east of France.

In the heart of Denver's manufacturing centre the American Coal Refining Company has four acres of land, upon which it has been constructing a plant to commercialize the fact that coal and lignite can be advantageously made to yield, by low temperature distillation, most valuable products, and incidentally a high-class industrial and domestic fuel in the form of briquettes and ovoids (locally called carbonets).

The initial capacity of the Denver plant is for 500 tons a day, with provision to double the output when required. The ovens are in groups or blocks of four, and are of the Belgian improved coke oven type, 36 ft. long, 9 ft. high, and 18 in. wide, and are lined with special silica bricks. The walls are provided with longitudinal flues, in which the flame and hot gases are circulated from gas burners located at the front ends. The waste heat leaving these flues is used for the steam boilers. Only a fraction of the gases evolved is used for heating purposes, and the remnant is passed over again in the ovens through the mass of baking lignite, after being superheated in flues beneath the floor of the oven. The temperature is raised to 500° C., and the distillation period averages about two hours.

The results recorded, per ton, are as follows: Irreducible gas, 10,000 cu. ft.; oils and tar, 13 to 14 gallons; sulphate of ammonia, 2½ lb.

The gases and vapours are treated in the usual manner—taken by exhaustor to scrubbers and condensers supplemented by electrical precipitating appliances to remove the non-gaseous matter, using electric current at 60,000 volts. The

oils and tar collected by distillation yield up to 150° C. 10 to 14 per cent of light oils; from 150° C. to 325° C. about 68 per cent of creosote and heavy oil. The residue amounts to about 10 per cent, and is hard, black pitch, very low in free carbon. Such distillation, as now carried on in Saxon-Thuringian lignite distillation works, with the addition of superheated steam, yields as high as 18 gallons of oils and tar, and the nature of the oils is more of a paraffinoid nature, and the volume of the irreducible gas considerably less.

References to the treatment of lignite will also be found in Chapter VII.

CHAPTER XVI

PEAT

PEAT exists in very considerable quantities in Great Britain and Ireland, and many attempts have been made to treat this in such a way that it would be suitable for industrial and heating purposes. At the present time, however, the treatment of peat, due to its large water content, has not responded satisfactorily to the methods which have been used.

In Canada, very extensive and exhaustive researches have been carried out upon the peat deposits of the eastern provinces, while in Germany and Sweden much practical work as well as chemical work has been done. In Great Britain, though several attempts have been made on a large scale to deal with peat mosses as the raw material for industrial processes, none has as yet attained to a commercial success.

It is the basin peat that is the most valuable¹ on account of its great thickness and uniformity and, as a rule, the more advanced stage of mineralization to which it has reached. In low-lying areas such as the Fens and the Eastern Counties there are also great deposits of peat which resemble basin peat in quality. These deposits are all mapped, and details of thickness, etc., can easily be obtained, if not already recorded.

It has been proved frequently that if peat be dried sufficiently and retorted a very fair yield of oils can be obtained, besides other organic compounds, while a good but light and not very hard coke remains as residue. Fresh peat, that is to say, the least modified in structure, will yield alcohol and various organic acids during the first stages of distillation, but in the latter stages the nitrogenous compounds are decomposed and the distillate becomes alkaline through the formation of ammonia, which can be collected as ammonium sulphate. In old and hard peat as much as 2 per cent of nitrogen has been recorded, indicating a very high theoretical yield of ammonium

¹ E. H. Cunningham-Craig in *A Treatise on British Mineral Oil*.

sulphate, approximately 211 lb. per ton. It is not possible to extract the theoretical yield in practice, but possibly two-thirds of it might be obtained. This points to the possibility of treating certain peat deposits chiefly for their yield of the sulphate, and considering any oils obtained as by-products. If such a process can be put upon a commercial basis, it would be possible to establish retorting works in several parts of the country, and to increase the indigenous supply of oil considerably.

An interesting report was made a year or two ago on peat from Shetland, which is of exceptional value in that it is high in volatile matter and low in ash and mineral matter. The nitrogen content was good, while sulphur was low, and in carbonizing, peat practically free from sulphur would be obtainable. Peat on being carbonized forms an extremely good charcoal which can be employed for metallurgical purposes or as a deodorizer, as well as in connection with the decolorization of sugar and other organic products, while it is eminently suitable for the suction gas producer.

If the peat is partially dried and put through a producer, large volumes of gas are obtained, which gas could be utilized for heating purposes or for operating gas engines. In addition to these gas products, 60 lb. of sulphate of ammonia per ton, as well as a tarry oil, may be obtained. The peat could also be put through a low temperature carbonization plant for the production of crude oil and petrol in addition to the charcoal referred to. An analysis of this Shetland peat, carried out under the supervision of Dr. J. B. Garbé, shows that it contains 73.80 per cent volatile matter and 21.43 per cent moisture, while the material dried at 105° C. shows 66.65 per cent volatile matter, 3.88 per cent ash, 29.47 per cent fixed carbon, 1.04 per cent nitrogen, and .70 per cent sulphur.

The quantity of charcoal recovered per ton of peat amounted to over 12 cwt., and of dried charcoal over 6 cwt., or a total yield of 33.92 per cent of the peat carbonized. The analysis of dried charcoal at 105° C. showed that it consists of—volatile matter 18.62 per cent, ash 9.95 per cent, fixed carbon 71.43 per cent, and the nitrogen and sulphur amounted to approximately .95 per cent each. The total quantity of sulphate

of ammonia obtained from the water produced during carbonization and from the scrubbing of the gas was 16.33 lb. per ton of the peat.

The report made gives details in regard to the oil obtained and an analysis of the various oil fractions.

The gas given off from the peat on carbonization amounted to about 4,500 cu. ft. of a calorific value of about 500 B.Th.U., and this gas, scrubbed with oil, yielded 1.44 gallons of spirit per ton of peat carbonized. The spirit had a specific gravity at 15° C. of 0.7885. It is to be noted that this trial was carried out with the Tozer retort, that is, at 500° C., and that if effected to-day at a lower temperature, i.e. 350–400° C., less gas would be evolved and a larger proportion of oil obtained, and the oil would have been more of a paraffinoid than that referred to.

The yield of crude oil was equivalent to 23.38 gallons per ton of peat carbonized.

FRACTIONATION

							%
Water	.	.	.	.	.	.	35.20
Up to 170° C.	.	.	.	.	.	.	2.16
170°–230° C.	.	.	.	.	.	.	19.80
Residue	.	.	.	.	.	.	37.84

This is equivalent to 15 gallons of water-free oil per ton of peat carbonized.

Analysis of Oil Fractions.

FRACTION UP TO 170° C. This represents 0.5 gallons of oil per ton of peat carbonized. It is a motor spirit and would be mixed with the spirit obtained by scrubbing the gas. Therefore, the total yield is 1.44 plus 0.5 equals 1.94, or approximately two gallons per ton of peat carbonized.

FRACTION 170° TO 230° C. This represents 1.63 gallons per ton of peat carbonized. It is a light fuel oil.

Specific gravity at 15° C.	.	.	.	.	.	.	0.9196
Flash point	.	.	.	.	.	.	84° F.

It contains 22 per cent of phenols. These need not be removed if it is to be used as a fuel oil. The phenols make, however, a useful disinfectant and it might pay to remove them, particularly as the calorific value of the residual oil is

increased. The amount of phenols represents about 1 gallon per ton of peat carbonized.

After removal of the phenols the oil has the following constants—

Specific gravity at 15° C.	%
Flash point	0.8782
	112° F.

The residual oil might be used as a heavy oil, but it is better in the first place to remove the paraffin wax. This is rather difficult to carry out on a small scale but represents no difficulty on a commercial scale. The yield is about 10 lb. per ton of peat carbonized.

The peat charcoal could be either briquetted or else gasified in a producer to obtain gas for power purposes. A good recovery of ammonia would also be obtained—about 45 lb. per ton of charcoal gasified.

On a plant dealing with 100 tons of peat per 24 hours the following quantities would be obtained—

	Tons.	Cwt.	Qr.	Lb.
Charcoal	33	18	2	6
Sulphate of ammonia		14	2	9
Crude oil, 1,659 gall. (approximately)	7	8	—	14

After fractionation the crude oil would yield—

	Tons.	Cwt.	Qr.	Lb.
Spirit, including that obtained by scrubbing the gas, 194 gall. (approximately)		13	3	12
Fuel oil, 463 gall. (approximately)	1	15	—	15
Residual oil, 3,784 gall. (approximately)	18	11	2	16

If the charcoal were gasified in a producer about 110,000 cu. ft. of gas of 130 B.Th.U. would be obtained from each ton of charcoal and from 45 to 50 lb. of sulphate of ammonia.

Starting with 100 tons original peat, after low temperature carbonization, 33 tons 18 cwt. 2 qr. 8 lb. of charcoal is obtained. This amount of residue if treated in a producer should yield approximately 3,732,143 cu. ft. of gas of 130 B.Th.U., and from 13 cwt. 2 qr. 15 lb. to 15 cwt. 0 qr. 16 lb. of ammonium sulphate.

APPENDIX

OIL FROM COAL, ANTHRACITE, LIGNITE, PEAT, ETC. BY "HYDROGENATION"

THE production of oil by hydrogenation of organic matter is not new. In 1849 Berthelot produced petroleum from coal by hydrogenation, and subsequently a good deal of research work was carried out in that direction, namely, the production of oil of a paraffinoid character by the hydrogenation of heavy oils. The treatment of coal and other carbonaceous matter by this method has been actively followed in England, Belgium, Germany, etc., and Professor Bergius a few years ago created quite a stir at a British Association meeting at Edinburgh in a paper on the subject.

The application of what is known as the "Bergius" process is claimed to be carried out on an industrial scale in Germany. The process, in this instance, employs such an abnormally high pressure which, together with the temperature used, made the work more dangerous than the manufacture of high explosives. The operations are conducted within high, thick walls, the necessary manipulation being effected by electric current handled by operators carefully concealed in a dug-out outside.

The operation consists more or less in treating a certain special quality of coal, of which there are considerable quantities in England, Belgium, France, and other countries. The coal is submitted to the action of hydrogen or of methane, or both, under high pressure, 234 to 250 atmospheres, or 3,440 to 3,675 lb. per square inch, and even higher, and a temperature of about 434° C. The initial pressure of hydrogen is 100 atmospheres, the temperature is gradually increased up to 434° C., where the pressure reaches 234 atmospheres. This pressure and temperature is retained for two hours, when the pressure falls gradually to 171 atmospheres, and after cooling, the pressure is reduced to 65 atmospheres. Another charge of hydrogen up to 80 atmospheres is then introduced. The temperature is

raised to 434° C. and the pressure reaches 205 atmospheres. After another two hours the pressure drops to 171 atmospheres, and after cooling again it falls to 65 atmospheres. The reaction being completed, the composition of the gas (originally hydrogen) is, after the first operation—

Hydrogen	.	.	.	.	%
Saturated hydrocarbons	.	.	.	.	68.4
					13.5

and the second operation—

Hydrogen	.	.	.	.	%
Saturated hydrocarbons	.	.	.	.	11.7
					75.2

The liquid obtained is dark and syrupy, with only the mineral ashes of the coal remaining in suspension. This liquid, submitted to a succession of such operations, finally yields light hydrocarbons, similar to those of natural crude oil. The process undoubtedly indicates that certain coals (not having more than 85 per cent of fixed carbon) are susceptible under certain treatment of being transformed into liquid hydrocarbon material.

Professor Bergius records the following production from such liquid—

Motor spirit	.	.	.	.	.	%
Heavy oil (suitable for Diesel engines)	.	.	.	.	.	30
Heavy oil (to be used as fuel, or to be treated again)	.	.	.	.	.	30
Irreducible gas	.	.	.	.	.	10
						<hr/> 100 <hr/>

The high temperature and dangerously high pressure employed are a great drawback to the adoption of such a process, and we believe that the real solution of the matter lies in the discovery and use of a proper catalyser, which will enable the transformation to be carried out with much lower temperatures and pressures. This idea is being developed in England and Belgium at the present time, and considerable success has already been attained in this direction. We have, indeed, obtained particulars from a private fuel research station, operating in the neighbourhood of London, of results

secured on the lines referred to. These results are the outcome of over ten years' patient and elaborate investigations.

LIQUID CARBONIZATION

The treatment of coal, lignite, shales, peat, sawdust, etc., and any matter of a carbonaceous nature is not only carried out by carbonization at low temperature and with the use of steam, but involves a more complex and, it appears, successive process by which materials of a certain quality are made to yield a considerable amount of oil and gas, leaving practically only solid ashes.

The first system is termed "dry progressive distillation" and the second "liquid carbonization." Really astonishing results are recorded from these methods applied to all descriptions and qualities of coal, brown coal, lignite, shales, cannels, etc., from England and all parts of the world.

It has been proved that these materials can be totally transformed into oil, leaving only a mineral residue of ashes.

We have selected from a long list of results the following examples treated by the two methods referred to—

	Dry Progressive Distillation in Test Report up to gall. per ton	Liquid Car- bonization up to gall. per ton
ENGLAND—		
Shipley cannel	56	60-70
Newbury, Somerset	30.2	90-100
Dunkerton	34.2	50
Mells, Somerset	31.08	60
FRANCE—		
Uroz	5-22.4	40-50
Le Tresquet	26.70	60
Demoulins	31	70
Montrambert	35-40	60
Gard, No. 1 sample	22.4	60-70
INDIA—		
Bikanir brown coal	26.1	65-96
AUSTRALIA—		
Morwell brown coal (dry)	20-40	50
CANADA—		
Middle Fork Old Man River	30	70
CHILE—		
Lirqueen	30	62.72

	Dry Progressive Distillation in Test Report up to gall. per ton	Liquid Car- bonization up to gall. per ton
BRAZIL—		
Crissiuma	22-30	70
San Jeronymo (washed)	25	66
SPITZBERGEN	39.2	55
LIGNITE—		
Canada, Galt	26.8	66-95
France, Basses Alpes	30	50-60
" Landes	19	50-60
Vladivostock	26-31.2	70
SHALE—		
England, Newbury	25	50-60

MISCELLANEOUS ANALYSES

AVERAGE ENGLISH COAL

Treated in the Nielsen retort. Temperature, 371° C.-426° C.

Tar oil obtained 20 gallons per ton—	%
Light oil (up to 180°)	4.75
Medium oil (180°-230°)	20.00
Medium heavy oil (230°-270°)	14.50
Pitch	35.00
Loss	1.75

DERBYSHIRE COAL

(Unwashed Smalls)

Approximate analysis of coal—	%
Moisture	5.30
Volatiles	24.95
Fixed carbon	54.90
Ash	14.85

Results of treatment by Freeman multiple retort—

	%	lb.	
Gas (670 B.Th.U.).	3.036	68.00	= 1133.44 cu.ft.
Oil	11.514	257.91	1.01 sp. gr.
Water	9.900	221.76	
Residue	75.550	1692.32	
Maximum temperature, 883° F. (472° C.).			
Production of oil ceased at 820° F. (438° C.).			

BROWN COAL

(South Australia)

Tests carried out by F. Lamplough, M.I.A.E., M.I.Pet.Tech., under the supervision of Dr. J. B. Garbé, showed that one ton contains 1307.5 lb. of volatile matter, including moisture, and 932.5 of residue in the form of coke.

Products obtained were—

Oil	100.2 lb.
Coke	932.5 lb.
Water	1207.3 lb.

This is equivalent to 10.2 gallons of oil to the ton. With the whole of the moisture removed, this quantity of oil would be recovered from 1032.7 lb. of perfectly dry coal, or equal to 22.03 gallons of oil to the ton. These results were obtained with the Lamplough-Harper system at temperature 350-400° C.

In a Bench retort, F. Lamplough, M.I.A.E., obtained 22.4 gallons of water and 73.3 gallons of oil to the ton by dry distillation.

ANALYSIS OF COAL

	%
Moisture	1·95
Volatile matter	19·12
Ash	11·21

	High Temperature.	Low Temperature.
Duration of test.	4 days	4 days
Temperature taken outside retort	{ 1400°C. 2562°F.	{ 978°C. 1793°F.
Coal carbonized	43·1 tons	12·97 tons
Coal carbonized per retort in 24 hours	2·69 tons	0·81 tons
Total gas made, corrected to normal temperature and pressure	495,280 cu. ft.	94,326 cu. ft.
Gas made per ton, corrected	11,491 "	7,272 "
Make of gas per retort, per 24 hours	30,955 "	5,895 "
Illuminating power, No. 2 Met. burner	6·33 candles	9·25 candles
Sperm value	249	230·6
Calorific value, gross	441·1	479·4
" " net	395·5	428·9
Total B.Th.U. of gas made per ton of coal	5,068,680	3,486,196
Coke per ton	16·1 cwt.	15·8 cwt.
Coke made, per cent	80·7%	79·1%
Tar made per ton of coal carbonized (dehydrated)	6 gall.	10·89 gall.
Sulphate of ammonia made per ton of coal carbonized	14·6 lb.	26·2 lb.

Specific Gravity	1.051 at 60° F.	Specific Gravity	1.036 at 60° F.
0°-168° C.	2.9%	9°-160° C.	5%
168°-228° C.	11.6%	160°-240° C.	16.5%
228-268° C.	7.9%	240°-360° C.	27.0%
		Pitch	51.5%
Benzol in tar	1.53%	Benzol	1.68%
Toluol	0.59%	Toluol	0.34%

ANALYSIS OF COAL

Moisture	2.29
Volatile matter	31.64
Ash	6.37

¹ The temperature at which the second test was made is not now regarded as low temperature, and is given for comparison purposes. The character of the oils produced will also be noted.

ANALYSIS OF GAS

ANALYSIS OF TAR

YORKSHIRE CANNEL (PERKIN)

Yield of sulphate of ammonia—3.2 lb.

The oil produced, on fractionation—

There was only a small portion of paraffin wax, which was not estimated.

SCOTTISH CANNEL (PERKIN)

Yield of crude oil—37 gall. per ton of coal.

On fractionation the following products were obtained—

Light oil to 150° C.	.	.	.	.	.	.	Gall.
Fuel oil	.	.	.	.	.	.	22

F. D. Marshall gives the following set of results from Tyne Boghead Cannel—

	Gall.
Oils (dry) per ton carbonized	53.5
Spirit stripped from the gas, distilled to 170° C.,	
Sp. gr. 796	4.92
Total oil and spirit	58.52

The crude oil, on being distilled, gave—

	Gall.	
To 170°, 6%	3.12	(Sp. gr., .796)
170°–350°, 67%	38.00	
Pitch, 26.5%		

The coke production was 70% of the cannel used.

	%
Ash in coke	20.4
Volatile matter	8

The quality of the coke was good, especially for gas producers.

From a 45-ton test of a cannel the same authority gives—

	Gall.	
Crude oil	39	(Sp. gr., .840)
Spirit from gas	5	
	<hr/> 44	

Coke (with quenching water)—1,708 lb. per ton carbonized.

From a Northumberland cannel of the composition—

	%
Water	0.5
Fixed carbon	52.3
Ash	20.2
Volatile matter	27.5
„ in coke	2.6

there was obtained crude oil 30.67 gall., of specific gravity 0.968, and settling point 75° F.

From an Irish cannel (residue gasified)—

58.5 gall. of oil.

54.5 lb. sulphate of ammonia.

58,000 cu. ft. of producer gas of 130 B.Th.U.

From Wemyss cannel—

	A.	B.
Motor spirit, 1st grade	3.6	—
„ „ 3rd grade	—	6.6
Intermediate oils	7.3	—
Fuel oil	62.4	66.7
Scale	5.0	5.0
Pitch	8.7	8.7
Loss in refining	13.0	13.0
	<hr/> 100.0	<hr/> 100.0

NOTE.—The motor spirit (amounting to 3% of the crude oil yield) absorbed in the scrubbers during the distillation of the cannel coal has not been included in the above table.

MISCELLANEOUS TESTS ON CANNELS

<i>Boghead Cannel-Oil</i>		%
Specific gravity	.	0.916
Water	.	0.5%
Distilling up to 170° C.	.	8%
" 170°-230° C.	.	10%
" 230°-270° C.	.	13% (Sp. gr., 0.832)
" 270°-350° C.	.	38% (Sp. gr., 0.886)
Pitch	.	30.5%
Tar acids averaged 9% of the total distillate.		

<i>Wemyss Cannel-Oil</i>		
Specific gravity	.	0.904
Water	.	1.2%
Sulphur	.	1.15%
Yield of fuel oil	.	77.0%
Specific gravity of fuel oil	.	0.933

<i>Cannel-Oil</i>		
Specific gravity	.	0.940
Water	.	7.0%
Distilling up to 170° C.	.	6.5%
" 170°-230° C.	.	8.0%
" 230°-270° C.	.	9.5%
" 270°-330° C.	.	27.0%
		<u>58.0%</u>

Tar acids averaged 7% of the total distillate.

Another cannell yielded 37 gall. of oil per ton, which was split up into—
 3% of motor spirit
 9% of intermediate oil
 51% of heavy fuel oil.

The above assays do not include the light oils recovered from the gas.

NOTE.—The above analyses are taken from *A Treatise on British Mineral Oil*, by J. Arthur Greene, A.M.Inst.P.T.

GERMAN LIGNITE

Treated in vertical retort, with steam injected at a German works.

Yield of oil per ton, 18 gall., the results of fractionating the oil—

	Specific Gravity
Benzene, 130°-170° C.	.710-.780
Kerosene, 170°-220° C.	.750-.820
Solar oil, 220°-290° C.	.880-.900
Paraffin wax, 320° and upwards	.880-.910

NORWELL (VICTORIA) LIGNITE

Yield of oil per ton, 13 galls.

Results of analysis—	%
Motor spirit	9.6
Benzene	22.5
Kerosene	19.5
Lubricating oils	37.4
Paraffin wax	11.0

Maximum temperature 400° C. with superheated steam.

(Tests carried out under supervision of Dr. J. B. Garbé.)

ANALYSES OF GASES FROM VARIOUS MATERIALS

The analyses of the gases evolved from each of these fuels at low temperature are given as follows¹—

Fuel.	Range of Heating.	Loss of Weight per cent.	GAS ANALYSES. ²						
Wood	150-188°	51.9	CO ₂ 58.6	C ₆ H ₆ 0.5	C ₂ H ₄ 0.6	CO 35.0	H ₂ 1.0	CH ₄ 1.3	N ₂ 3.0
Brown Lignite. . . .	230-320°	26.8	55.6	0.6	1.0	24.7	0.3	11.4	6.4
Black Lignite	260-340°	31.0	49.3	0.9	0.8	19.5	Nil	19.5	10.0
Illinois Coal	300-330°	23.7	24.1	2.8	2.2	10.6	3.4	43.3	13.6
Gas Coal	300-360°	12.2	7.3	0.5	1.4	6.0	14.6	57.4	12.8
Smokeless Coal	330-400°	10.0	6.5	2.6	2.3	4.1	9.7	53.5	21.3
Anthracite	230-475°	0.7	4.6	1.3	0.4	2.6	Nil	70.6	14.8

¹ *Monograph on the Constitution of Coal*, by Marie C. Stopes, D.Sc., and R. V. Wheeler, D.Sc.

² The gases estimated as "benzene" were in all probability the higher olefins and the "methane" no doubt included the higher paraffins.

LOW TEMPERATURE OIL AND COAL TAR

The relationship between the old low temperature oils and coal tar petroleum may be seen from the analyses on the opposite page¹—

NORFOLK SHALE

Treated in the Freeman retort.

	%	lb.
Total water	13.55	303.52
Oil	17.95	402.08
Residue	60.71	1359.90
Gas—3,500 cu. ft.	7.42	166.21
Loss	37	8.29

Sp. gr. of oil, .973.

Quantity of oil per ton of raw shale, 41.32 galls.

" " " dry " 47.79 "

Maximum temperature at which distillation of oil ceased, 680° F. (360° C.).

Results obtained in Bench retort by F. Lamplough, M.I.A.E.—

	A	B	C	D
	galls. p.t.	galls. p.t.	galls. p.t.	galls. p.t.
Water	13.4	19	13.44	11.2
Oil	19.4	31	10.98	37.1

Forbes Leslie points out¹ that the Norfolk shales differ decisively from the Boghead and torbanites; they more nearly resemble the Scotch calciferous sandstone shales. The specific gravity of the Norfolk shale is about 1.3. The shale yields 1% of oil to ether.

ANALYSIS OF NORFOLK SHALE

	Smith's Series.	Puny Drain Series.
	%	%
Moisture	9.8	8.0
Volatile organic matter	35.1	31.7
Fixed carbon	15.3	16.3
Ash	39.8	44.0

A Treatise on British Mineral Oil, by J. Arthur Greene, A.M., Inst. P.T.

TARS (MOORE)												
DESCRIPTION.	Sp. Gr. 15.5° C.	Percentage of					Ash.	Coke.	Calorific Power, Dry Tar.		Free Carbon.	REMARKS.
		H ₂ O.	C.	H.	O + N.	S.			Gross.	Net.		
Horizontal retort tar . . .	1.180	1.75	91.5	5.2	2.6	0.5	0.2	24.0	9,093	8,645	18.2	High temperature High temperature Note effects of lower temperatures
Inclined retort tar . . .	1.157	1.11	89.9	6.0	3.6	0.5	0.02	18.5	9,096	8,671	14.0	
Vertical retort tar . . .	1.089	2.25	98.0	6.8	3.8	0.6	0.03	6.1	9,246	8,664	1.7	
Otto Hilgenstock coke . . .	1.208	6.0	90.0	5.4	3.8	0.8	0.02	26.8	8,921	8,624	23.9	Note increase of hy- drogen percentage
Simon Carves . . .	1.090	0.05	88.1	5.6	6.1	0.2	0.02	6.0	9,695	9,261	trace	
Chamber-oven tar . . .	1.082	1.29	88.2	6.9	4.6	0.02	trace	7.3	9,229	8,737	3.0	
Low temperature carbonization tar	1.053	3.0	85.8	8.1	5.5	0.9	0.11	8.2	9,196	8,776	2.2	

FUEL OILS (MOORE)												
DESCRIPTION.	Sp. gr. 15.5°C.	Percentage of					Ash.	Coke.	Calorific Power, Dry Tar.		Free Carbon.	REMARKS.
		H ₂ O.	C.	H.	O + N.	S.			Gross.	Net.		
Tarless Fuel Co.'s oil (distilled from tar)	0.995	trace	82.6	8.6	8.8	9.50	0.10	1.52	9,472	9,008	—	
Scottish shale oil	0.945	1.6	87.0	9.50	1.04	2.35	0.11	0.18	9,917	9,245	—	
Mexican fuel oil (petroleum)	0.952	1.0	83.6	10.9	1.5	2.85	0.17	12.2	10,350	9,734	—	
Coal-tar creosote.	1.053	trace	89.7	7.4	2.23	0.66	trace	1.30	9,342	8,964	—	
Wemyss canal fuel oil (Dunstan)	—	—	85.4	12.5	1.38	0.72	—	—	10,520	—	—	

ANALYSIS OF THE ASH						%
Silica	.	.	.	.	.	49.50
Alumina	.	.	.	.	.	20.20
Ferric oxide	.	.	.	.	.	10.27
Lime	.	.	.	.	.	11.68
Magnesia	.	.	.	.	.	1.22
Sulphuric acid	.	.	.	.	.	6.30
Phosphoric acid	.	.	.	.	.	0.83
						<hr/> 100.00 <hr/>

KIMMERIDGE SHALE

F. M. Perkin quotes the following analyses of Kimmeridge shale and the oil therefrom¹—

	%
Moisture	5.02
Volatile matter	41.20
Mineral matter	44.71
Fixed carbon	9.07
Sulphur	5.03
Nitrogen	1.23

One ton of the shale yielded 64.75 gall. of crude oil, which contained—

Water	30.25 (45-86%)
Dry oil	34.50
	%
Sulphur in crude oil	3.74
Sulphur in dry oil, <i>circa</i>	7

SOUTH AFRICAN TORBANITE

Maximum temperature, 400° C.

	%	
Moisture	0.80	= 150 galls. of
Volatile matter	59.70	oil per ton.
Ash	21.08	
Fixed carbon	18.42	

(Tests carried out under supervision of Dr. J. B. Garbé.)

SOUTH AFRICAN (E. TRANSVAAL) SHALE

Total yield of free water, 90.6 galls. to ton. Spent shale, 19.75 lb.

Distillation of crude oil carried on to 300° C., and yielded 3.7 galls. of kerosene and 10.95 galls. of middle oil to the ton.

Total spirit yields 5.6 galls. to the ton.

Spirit fractions	c.c.	
50°	2	
60°	5	
70°	8	
80°	14	
90°	23	
100°	47	
110°	67	
130°	121	
140°	150	
150°	185	sp.gr. .720
160°	230	„ .755

Spirit fraction when cleaned up will average about .730 sp.gr.

(Tests carried out in Lamplough-Harper retort, under supervision of Dr. Garbé.)

¹ *A Treatise on British Mineral Oil*, by J. Arthur Greene, A.M., Inst. P.T.

LOW TEMPERATURE DISTILLATION

ANALYSES OF OILS OBTAINED FROM SOUTH AFRICAN TORBANITE BY
THE GRIFFITHS AND LAMPLOUGH LOW TEMPERATURE SYSTEMS

GRIFFITHS (without steam)			LAMPLOUGH (with steam)		
Yield of crude oil, 100 gall. to the ton.			Yield of crude oil, 147 gall. to the ton.		
Sp.gr. .887			Sp.gr. .880-.866		
	%	Sp.gr.		%	Sp.gr.
Spirit . . .	6.00	.739		6	.730
Burning oil . .	24.85	.749-.812		36	.810
Middle oil . . .	6.60	.850		11	.850
Lubricating and heavy oil }	38.00	.855-.864		17.3	.880
Paraffin wax . .	4.00	solid		1.5	solid
Residue . . .	20.55	—		28.2	—

Another sample of oil obtained by Lamplough process (steam) gave the following on fractionation—

From	%
60° C.-160° C.	9.20
„ 160° C.-210° C.	10.60
„ 210° C.-270° C.	17.55
„ 270° C.-310° C.	18.75
„ 310° C.-330° C.	12.50
„ 330° C.-350° C.	8.35
„ 350° C.-365° C.	4.75
„ 365° C.-400° C.	18.30 bitumen and loss

COAL AND TORBANITE

(Results of Tests obtained by Professor Stanley)

					galls. per ton
<i>Mooifontein</i> —					
Shale in roof					7
Coal 30" top					18
„ bottom					12
Torbanite					96
Sp. gr. of oil from coal . . . . .					.9
Torbanite					96
Sp. gr. of oil from coal . . . . .					.9
„ „ „ torbanite . . . . .					.82

Bankop—

Torbanite (1)	86 galls. per ton
„ (2)	56 „ „

Sandklip—

Shale galls. per ton	1	2	3
	18	7	18

VLADIVOSTOCK SHALE

On dry distillation from 100 grams—

	1	2
	Gall.	Gall.
Water	64.9	53.76
Oil	11.2	20.16

NOVA SCOTIA TORBANITE

(Distillation test in Lamplough-Harper retort)

Distillation commenced at 230° C., oil ceased to come over at 340° C.

Total yield of oil, 87.5 gall. per ton

" " spirit, 2.9 gall. per ton

" " kerosene, 3.7 gall. per ton

" " middle oil up to 300° C., 2.16 gall.

Spirit Fractions

°C.	c.c.
50	1
60	4
70	6
80	12
90	22
100	41
110	54
120	78
130	112
140	149
150	192 (Sp. gr. .741)

Kerosene

160	52
170	100
180	149
190	200
200	248 (Sp. gr. .800)

The oil from this shale has a wax basis.

ESTHONIAN OIL SHALE

Organic composition

	1 %	2 %
Carbon	70.52	72.82
Hydrogen	7.20	8.65
Nitrogen . . . . .	.30	.68
Oxygen	21.98	16.24
Sulphur	—	1.60

Volatile matter, 54-56 per cent.

Yield of crude oil per ton, 80-84 gall., sp. gr. .950.

DISTILLATION OF CRUDE OIL

	%	Sp.gr.
Up to 120° C.	7.8	.758
120-170	8.0	.777
170-200	10.1	.789
200-240	11.7	.831
240-270	11.6	.851
270-300	8.5	.875
Steam distilled (a)	9.9	.959
" " (b)	6.2	.961
" " (c)	23.2	1.000
Residue "	3.0	—

Laboratory test by the late Professor F. E. Weston, B.Sc., F.I.C.)

THE MACLAURIN SYSTEM

RESULTS OBTAINED WITH DIFFERENT DESCRIPTIONS OF MATERIAL

ANALYSIS OF FUEL.	Canneloid No. 1.	Bituminous No. 2.	Anthracite No. 3.
	%	%	%
Moisture	0.70	2.22	1.22
Volatile	26.04	19.02	6.72
Fixed carbon	25.52	26.48	36.48
Ash	49.74	52.28	55.58

YIELDS OBTAINED PER TON.	Canneloid No. 1.	Bituminous No. 2.	Anthracite No. 3.
	%	%	%
(1) Gas in cubic feet of 150 B.T.U.	46,767	69,240	60,800
(2) Oil (gallons)	25.8	6.7	2.0
(3) Sulphate of ammonia (lb.) .	8.5	17.0	10.3
Calorific efficiency of test run .	80.7	88	72

This system is specially suitable where gas is of industrial value.

RESULTS OF TEST OBTAINED BY THE GLASGOW
CORPORATION OFFICIALS ON THE MACLAURIN PLANT

COAL USED DURING TEST

The coal used during the test was Carron Lower Coxrod coal. It appeared to be a well-screened coal with about 70 per cent large lumps, of a hard nature and dull appearance, with lustrous streaks. There was a small percentage of bright soft coal, and by its general appearance and composition one would expect it to be fairly good coking coal.

ANALYSIS OF COAL				%
Moisture . . . . .	.	.	.	7.70
Volatile matter . . . . .	.	.	.	30.50
Fixed carbon . . . . .	.	.	.	53.70
Ash . . . . .	.	.	.	8.10
				100.00
Sulphur . . . . .	.	.	.	0.65
Specific gravity . . . . .	.	.	.	1.34
Calorific value . . . . .	.	.	.	12,300 B.Th.U./lbs. or 27,552 therm/ton

ANALYSIS OF COKE				
	Large Coke	Smithy Char.	Peas	Breeze
	%	%	%	%
Moisture	2.30	2.95	3.55	5.10
Volatile matter	3.00	3.30	3.50	3.30
Fixed carbon	81.20	78.25	71.95	58.20
Ash	13.50	15.50	21.00	33.40
	100.00	100.00	100.00	100.00
Sulphur	0.44			
Specific gravity	1.11			
Calorific value (B.Th.U.)	12,600	12,196	11,283	9,203

COKE SIEVING TESTS

	%	
Large coke	73.50	
Smithy char.	10.56	(through 1 in. mesh)
Peas	6.92	" $\frac{1}{2}$ "
Breeze	9.02	" $\frac{1}{4}$ "
	<u>100.00</u>	

DISTILLATION TEST ON SEPARATED OIL

	%
Moisture	1.70
0°-120° C.	0.64
120°-230° C.	5.47
230°-270° C.	14.14
270°-320° C.	16.08
320°-345° C.	9.96
Pitch	48.50
Loss	<u>3.51</u>
	<u>100.00</u>
Specific gravity	1.032

GAS ANALYSIS

	%
Carbon dioxide	6.0
Hydrocarbons	1.0
Oxygen	0.4
Carbon monoxide	15.9
Methane	12.4
Hydrogen	16.8
Nitrogen	<u>47.5</u>
	<u>100.0</u>

HEAT BALANCE

	B.Th.U.	Therms
1 ton Carron Lower Coxrod coal	at 12,300 per lb.	275.52
	Total .	<u>275.52</u>
8.05 cwt. large coke	at 12,600 per lb.	113.60
1.16 cwt. smithy char.	" 12,196 "	15.85
.76 cwt. peas	" 11,283 "	9.60
.99 cwt. breeze	" 9,203 "	10.20
5.60 gal. dry oil =		
1.44 cwt.	" 16,600 "	26.73
7.731 cu. ft. gas	" 247 cu. ft.	68.50
Loss		<u>31.04</u>
	Total .	<u>275.52</u>

The thermal efficiency on the test works out at 88.75 per cent. The yield of sulphate of ammonia is 17.3 per ton of coal. The coking index of the coal was 13.

LOW TEMPERATURE DISTILLATION

Actual results when running the plant for smokeless fuel and furnace coke—
The tests were made at Grangemouth in September, November, and
December, 1921, and February, 1922.

The results given below were agreed to by the parties interested.

	Sept., 1921	Nov., 1921	Dec., 1921 Glasgow Corporation	Feb., 1922
Nature of Coal : Mixture of splint and free coal.				
Smoking index	13	13	13	16
Throughput — tons	200	200	100	106
„ per day „	17·66	20·70	20·88	18·70
Measurements on — tons	70	192	82·80	106

YIELDS PER TON OF COAL

GAS—				
Cubic ft.	32,641	32,447	27,731	35,882
B.Th.U.'s per cu. ft. (gr.)	247	230	247	237
Total therms	80·60	74·70	68·50	85·00
OIL—				
Gallons, dry	11	16	15·60	14·75
SULPHATE OF AMMONIA (lbs.)	16	13	17·30	26·10
COKE—				
Large, cwts.	7·54	8·23	8·05	7·16
Smithy char, cwts.	1·85	·83	1·16	1·13
Breeze	2·04	1·64	1·75	1·13
Total	<u>11·43</u>	<u>10·70</u>	<u>10·96</u>	<u>9·42</u>
Steam, per ton of coal (lbs.)	500	340	553	285
		including two pumps.		

EXTRACT FROM PAMPHLET ISSUED BY THE MINISTRY OF RAILWAYS, BELGIUM, RELATIVE TO SPECIFICATIONS OF BRIQUETTES, ETC.

BRIQUETTES

General Conditions of the Two Types of Briquettes

*Nature of the Pitch and Quantity.*¹ The pitch should be dry
or semi-bituminous (semi-rich), and should be obtained
exclusively from coal tar. The amount of water should not
be more than 1 per cent, and of ash 1 per cent, and the dis-
tillation should be in a closed vessel, in a reducing atmosphere,

¹ It is not absolutely necessary that pitch should be used. Some briquettes
made with the help of a binder other than pitch will be allowed if the bri-
quettes, after preliminary treatment, are found to possess the necessary
qualities, from the points of view of evaporation, of resistance to weather
conditions, and of cohesion.

to give as residue a turgid coke, the weight of which should not be less than 30 per cent of the original quantity treated. The proportion of pitch put into the briquettes should be 10 per cent maximum.

Physical Qualities. The briquettes should be well compressed, lustrous, of uniform weight, and sharp-edged. The fracture should be clean and glossy (bright), the particles should be fine, pressed and homogeneous. They must be hard, and must conserve all their hardness up to 50° C. Their degree of cohesion must be at least 55 per cent and will be determined in the following manner—

Put 50 kilos of briquettes crushed into pieces of about 500 grammes, into a steel cylinder of 90 centimetres internal diameter and 1 meter long. The cylinder is made in three equal compartments by means of longitudinal steel diaphragms, projecting 20 centimetres. After having introduced the pieces of briquettes, close the cylinder and allow it to make 50 revolutions in two minutes. The residue is sifted on a meshed grating (three centimetre meshes), and the weight of the 50 kilos resting on the grating gives the cohesion.

Behaviour in the Fire. The briquette must ignite easily without splitting; must burn with a lively, clear flame without giving off sulphurous odours. Briquettes disclosing the presence of sticky slag or some fusible clinkers adhering to the grating, will not be admitted.

TYPE I

Nature of Coal. The coal used in the manufacture of No. 1 type of briquette must be semi-bituminous (semi-rich), or at least quarter bituminous, having a minimum of 13 per cent volatile matter and forming coke in burning; it should be of recent extraction.

Composition of the Briquettes. The amount of water in the briquettes should not exceed 4 per cent and the amount of ash should not be more than 9 per cent.

Practical and Laboratory Experiments of Schaerbeek. Type 1 briquette should conform to the following experiments, carried out on locomotives and in a boiler installed in a laboratory at Schaerbeek.

First Practical Experiment. On the journey from Termonde to Anvers G-C. and return by ordinary train type, 415 and 418, making the journey, including stops, in an hour and 15 minutes, and in 51 minutes respectively, the evaporation as given by one passenger locomotive, type 15, deep fire-box, with a minimum charge of 200 tons and a maximum charge of 250 tons, should not be less than 8 kilos of water per kilo of briquettes.

Second Experiment at the Laboratory of Schaerbeek. Independent of the above experiment, briquette type 1 should satisfy the following experiment, carried out at the laboratory of Schaerbeek, in a boiler fixed to a locomotive type 17 or 18, the pressure of that boiler being maintained at 14 kilos per square centimetre. These briquettes should be able to evaporate a minimum of eight kilos of water per kilo of combustible used, the temperature of the feed-water being admitted at 15° C.

Artificial draught will be produced by a steam jet in the chimney. The intensity of this draught will be measured by the space in the smoke-box and expressed in millimetres of water. It will be at least 1,500 mm. for type 1 briquette. The experiment will be conducted in the following manner—

Before the experiment the pressure of the boiler will be six kilos and the grating will be perfectly free from all kinds of combustibles. The briquettes to be experimented with will be broken into pieces of about 2 to 2.5 kilos. They will weigh exactly 75 kilos for the purpose of ignition and 600 kilos for the purpose of the trial.

Proceed then to ignite, completely using the 75 kilos to effect this and using the blower in the chimney to bring the pressure to 13 kilos. As soon as this is attained the experiment commences. Charge 200 or 300 kilos of briquettes and create in the smoke-box a depression of 150 mm. of water, allowing the vapour produced to escape in the chimney.

At the same time note the level of water in the boiler, and commence to raise the quantity of feed-water used. Continue to charge the briquettes in such a manner as to maintain a constant pressure of 13 kilos, maintaining an equal level of water, or very little below that existing at the commencement of the experiment.

When the 600 kilos intended for the trial have been completely charged, the movement should be maintained until the moment when the pressure descends to 9 kilos per square centimetre. Then cut off the depression in the smoke-box, and if the level of water is a little below that which existed at the beginning of the experiment, restore it exactly to its first height.

Note at this moment the quantity of water which has been introduced into the boiler since the commencement of the trial; that quantity of water is considered to represent that which has been vaporized by the 600 kilos of briquettes.

The minimum power of evaporation imposed should be three kilos of water per combustible utilized, supposing that the temperature of the feed-water is 15°C . If that temperature, at the time of the experiment, differs from 15°C , the figure obtained should be modified in a manner similar to that which has been indicated for the trial in a fixed boiler with small coal.

TYPE 2

Nature of the Coal. The coal used in the manufacture of No. 2 type of briquette must combine the conditions imposed on the semi-bituminous (demi-grâs) coal; it should contain from 14 to 16 per cent of volatile matter, should give a coke which is calcination-proof, hard and homogeneous, close-grained, and be of recent extraction.

Composition of the Briquettes. The amount of moisture in the briquettes should not exceed 4 per cent, the amount of ash should be 8 per cent maximum, and the amount of volatile matter should not be less than 17 per cent nor more than 22 per cent. The temperature of melting of the ash obtained by incineration should be verified at the laboratory of Schaerbeek, and should not be more than $1,350^{\circ}\text{C}$.

Practical Experiments and Laboratory Experiments of Schaerbeek. Type 2 briquettes should satisfy the following experiments, carried out on locomotives and on a boiler fixed in the laboratory of Schaerbeek—

First Practical Experiment. On the journey from Bruxelles-Nord to Verviers, by a direct train of type 624, making the

journey, including stops, in 2 hours 50 minutes, the evaporation given by a locomotive of type 17 with a minimum charge of 205 tons and a maximum charge of 250 tons, or by a locomotive type 18 with a minimum charge of 250 tons and a maximum charge of 300 tons, was not less than 9 kilos of water per kilo of briquettes.

Second Experiment at the Laboratory of Schaerbeek. Independent of the experiment above mentioned, type 2 briquettes should satisfy a trial in a fixed boiler of locomotive type 17 or 18. That trial will be carried out at the laboratory of Schaerbeek, under the same conditions as that provided for type 1 briquettes. For type 2 briquettes, however, the minimum depression in the smoke-box will be 175 millimetres, and it should be able to evaporate a minimum of nine kilos of water per kilogramme of combustible used. The temperature of the feed water should be 15° C. If during the experiment this temperature is other than 15°, account should be taken of it in the manner indicated previously for the trial in a fixed boiler with small coal.

ADDENDUM

REFERENCE is made in the early part of the Appendix to the experiments which have been carried out in connection with the hydrogenation of heavy oils, coal, lignite, asphaltum, etc. The most recent development in this direction is the formation of a company by several prominent mining and metallurgical firms in France, Belgium, and Luxemburg, with a large capital, to work the process on a commercial scale, on the lines referred to in our previous notes. A very efficient method of catalyzation is employed, enabling the system to be worked at a reasonably low pressure and at a temperature of from 400° C. to 500° C. only.

Furthermore, in some districts of Belgium, where highly bituminous coal is produced, there are two large installations, working at low temperature (400° C.) for the extraction of paraffinoid oil, with combined treatment at high temperature, through which the full content of nitrogenous matter is transformed into ammonia. This is not an experimental plant, but is capable of treating about 1,000 tons per day. Several large metallurgical firms are also erecting low temperature (400° C.) distillation plants in Belgium, the chief one being for the purpose of producing semi-coke for use as pulverized fuel for boiler and metallurgical furnaces belonging to the firms referred to.

Additional details of these plants cannot be included here, owing to the exigencies of space, but the authors will be pleased to supply further information to any reader interested.

CHEMICAL ANALYSIS OF OIL SHALES¹

	C.	H.	N.	S.	O. (By dif.)	Ash.	CH. (ratio).	OH. (G.pr.T.)
Scotch (Broxburn)	19.51	2.48	0.69	1.36	3.31	72.65	7.86	23.3
Scotch (Pumpherston)	24.88	3.67	0.68	0.80	0.07	61.90	6.78	31.0
Australian (Commonwealth)	63.58	7.81	0.81	0.43	4.41	22.96	8.14	10.8
Utah (Soldier's Summit)	13.51	1.70	0.39	0.28	18.00	66.12	7.94	16.8
Nevada	37.65	5.43	0.39	1.08	10.04	46.21	7.24	86.8
(Elko)	8.61	1.44	0.48	1.12	6.76	81.59	5.98	8.4
Colorado (Grand Valley)	23.67	3.50	0.66	1.78	3.79	66.60	6.76	63.5
California (Lone)	50.95	5.77	0.42	2.12	18.06	22.68	8.83	51.8
Lignite (Black, United States)	54.91	6.39	1.02	—	32.54	5.14	8.59	—
Crude Shale Oil (Autun, France)	79.70	11.80	—	—	8.50	—	—	—
Crude Petroleum (Penna Heavy)	84.9	13.7	—	—	1.40	—	—	—
Crude Petroleum (California)	84.00	12.70	1.70	0.75	1.20	—	—	—
Asphalt (Trinidad)	82.60	10.50	0.50	6.50	Nil	—	—	—
Cannel (English)	79.23	6.08	1.18	—	7.24	4.84	—	—

¹ A Chemical Examination of the Organic Matter in Oil Shales by Ralph H. McKee and Ralph T. Goodwin, Department of Chemical Engineering, Columbia University.

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